COSTS AND EFFECTS OF A WATER QUALITY PROGRAM FOR A SMALL STRIP MINING COMPANY

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COSTS AND EFFECTS OF A WATER QUALITY PROGRAM FOR A SMALL STRIP MINING COMPANY

A Report Submitted to the

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FOREWORD

A. Purpose

In dealing with water supply storage in federal reservoirs Corps procedures are to compare the reservoir water costs with costs of various alternative means of obtaining the same quantity of water. The quality of the water supplied are also usually assumed as the same for all alternatives or are compared in unquantified terms. In dealing with releases from reservoirs for the purpose of enhancing downstream water quality and in comparing waste water management alternatives such a precedure can be inadequate since the costs vary with the quality of water to be achieved. The society may be willing to accept lower than a standard or assumed quality in light of lower economic costs or may in fact desire higher quality. It may also be willing to accept more water at a lesser quality or vice versa. New procedures are required which will accommodate a better range of choices and identify the absolute and relative value which society places upon the standard. Such procedures are of interest to both the Corps and the Environmental Protection Agency, particularly in light of greater emphasis on effluent permits for waste water discharges.

An opportunity to research the effects of water quality standards presented itself in an almost fortuitous manner with the availability of both the research talent and interest from Messrs. Dreese and Bryant and of detailed financial records from a cooperating strip mine firm operating in Southeast Ohio. Basically, the research strategy was to analyze the rational behavior of the firm confronted by a unique competitive environment and alternative water quality criteria. The analysis was to indicate the nature of the market, the nature of the firm's cost schedule as affected by water quality criteria, and the rational response of the firm. The response could be to reduce output or shut down, to increase output and capture available scale economies, or to essentially maintain production at current level. It was hoped that the analysis would lead to conclusions about the amount the firm would be willing to pay for someone else to manage their water quality for them, which is the traditional measure of national income benefits, and conclusions on the competitive structure of the industry when costs are internalized to the firm (the social costs resulting from the incidence of the quality regulation).

It was recognized that extensive case studies would have to be completed before the methodology of this pilot study could be accepted as a reasonable and effective method for evaluation.

B. Findings

A well developed analysis of the competitive environment of the target firm is presented, along with costs for several levels of technology capable of dealing with the acid produced by the firms mining operations. One of the important elements of the physical environment in which the firm operates is the significant levels of acid pollution existing because of both historical mining operation and natural geological processes. Present state law recognizes the severity of the existing situation by exempting several tributary areas (including the area worked by the target mine) from current water quality legislation, although certain Federal and State reclamation laws are applicable to the handling of spoil and revegetation.

There are provocative conclusions regarding the water treatment alternatives. There is available at least one level of acid water treatment technology which appears to be feasible for the target firm to adopt. The report also concludes that some of the more complex treatment processes possees scale economies which would preclude efficient adoption by a firm operating at the level of the target mine. Where there are substantial economies of scale in pollution control measures, greater concentration of firms can be anticipated--one of the costs of imposing environmental controls at the industry level.

C. Assessment

The report fulfills its purpose. It shows considerable merit in application of economic theory of the firm to analysis of environmental issues. As the report points out, firms which possess sufficient market power to practice price leadership can pass forward the costs of pullution control to consumers under conditions of price inelastic demand. Under these circumstances smaller firms could also pass some or all costs forward. Additional studies of larger firms would be warranted in order that the competitive environment and cost schedules facing them can be better understood.

The success of this type of analysis is completely dependent upon the availability of normally confidential financial records of business firms. It is hoped that the manner in which this case was analyzed, is indictive that sensitive and potentially competitively harmful details can be analyzed and presented in a way which protects the best interests of cooperating firms.

D. Status

This report demonstrates a technique which may be applicable to the Corps planner under special circumstances. As such, it is informative in nature.

The findings, conclusions and independent judgment of the team of researchers are their own. The report is not to be construed as necessarily representing the views of the federal government nor the Corps of Engineers. Policy and procedural changes which may result from this research will be implemented by directives and guidelines provided by the Chief of Engineers through command channels. Further research on this technique by IWR is dependent upon the critical response to this proposed research strategy and upon the priorities for research which reflect the relative urgency of this issue to Corps of Engineers program concerns.

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CHAPTER I

INTRODUCTION

Purpose of the Study

The primary purpose of the study is to investigate the possibility of using economic analysis in the study of water pollution control in general, and specifically to apply economic analysis to the current and proposed water quality program of a small, privately owned strip mining company located in southeastern Ohio.

Water pollution control is a priority item on the agenda of many individuals, firms and governmental agencies. Acid drainage from coal mines, both underground and surface, is an important source of pollution in those states where coal mining is a major industry. In the 22 states where strip mining takes place, the problems associated with acid drainage can be severe for localized areas. Of the coal tonnage stripped in the United States in 1968, about 81 percent was stripped in the states of Illinois, Indiana, Kentucky, Ohio, Pennsylvania and West Virginia, and in these states the pollution from acid drainage is especially severe. In the last two states, Pennsylvania and West

Virginia, acid drainage pollution is the number one water quality problem.[1]

While there is no lack of interest in acid mine drainage among government, academic and industry research people, there is a noticeable lack of research interest into the economic aspects of acid mine drainage.[2] A review of the water pollution control literature indicates that the technical aspects of water pollution control have been extensively researched, and that while the technology of pollution control is widely known in industry and government it is simply not being utilized.[3] This appears to be true of acid mine drainage control techniques as well.

What is implied by many researchers and specifically stated by some, is that the costs of pollution control should be shared by government and industry. The reason

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[1] Recent and historical documentation on strip mining and its attendant acid drainage problems appear in several governmental publications. One of the most thorough presentations is found in "The Incidence and Formation of Mine Drainage Pollution," Appendix C of the Report for Development of Water Resources in Appalachia. Office of Appalachian Studies, U.S. Army Corps of Engineers, 1969.

[2] David B. Brooks, "Strip Mine Reclamation and Economic Analysis," Natural Resources Journal, Vol. 6, No. 1 (January, 1966), p. 21.

[3] This point was emphasized by Mr. John L. Gillis, Senior Vice President of Monsanto Co., at the Governor's Industrial Development Conference, West Virginia University, June 3-4, 1970.

for this is that external costs of water pollution--what are frequently referred to as social costs--are hard to measure and hard to identify. Therefore, it would not only be inequitable to require firms to absorb the total costs of water pollution which are not measurable, but impossible since they are not identifiable. In effect, private costs of water pollution control should be borne by firms and external costs should be borne by society. Supporting this position is the economic argument that to force an individual firm to absorb all costs of its operations, internal and external, would be unfair to the firm since it would theoretically put the firm in an unfavorable competitive position and eventually out of business. This position is frequently taken by industry spokesmen, their associations, and others in reference to pollution control and reclamation costs.[4]

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[4] A typical coal industry position is that expressed by James Hyslop, Vice President of Consolidation Coal Company, when speaking about the economic costs of reclamation of the so-called "final cut" in a stripping operation:

> In presenting the economics of this problem, we have ignored the engineering difficulties involved and made the assumption that the material to be moved into the final cut could be handled by machinery at a nominal cost per cubic yard of 34½ cents. Under this very conservative estimate, the cost of doing this job would be $12,423 per acre of coal recovered from the total area mined and the cost per ton of coal

Although the costs of acid mine drainage control are only a part of reclamation costs, the economic position taken by coal stripping firms against acid drainage control is the same.

Specific Objectives

What are frequently ignored in the above arguments are several economic principles. Some of these principles are presented here. They are not meant to be exhaustive, but merely representative of the economics involved. First, if firms are competitive, their costs schedules should be quite similar, particularly in a given geographic area such as the coal fields of southeastern Ohio, where the firm to be studied is located.

> of filling the last cut would be $2.00. When it is remembered that coal from Ohio strip mines sells for less than $4.00 a ton, the economic absurdity of the proposal is obvious.

"Some Present Day Reclamation Problems: An Industrialist's Viewpoint," The Ohio Journal of Science, Vol. 64, No. 2 (March, 1964), p. 161.

A similar position is expressed in a more general statement made by Professor Edward J. Cleary, consultant to ORSANCO:

> Industries likewise abhor tying up capital in nonproductive waste treatment facilities; using authority-financed facilities not only avoids capital investment but permits an industry to charge off the rental payments as an operating expense for tax purposes.

"Water Quality Management," Water Pollution Control Federation Journal, Vol. 42, No. 2, Part 1 (February, 1970), p. 159.

If all producing firms practice similar acid control programs which they likely do in fulfilling the state law, then the costs of control should be similar for each firm. Therefore ceteris paribus, no individual firm would hold a competitive advantage or disadvantage.

Second, the firms should be able to pass part of the costs of acid drainage control on to customers depending, of course, on the degree of competition that exists. Third, what would limit the firms' ability to pass these costs on would be not only the degree of competition involved but the elasticity of demand for coal from these producers. If coal buyers compete in localized markets, which they likely do in this particular area, then the local demand for coal from the local producers would presumably be somewhat inelastic thus enabling coal firms to pass the costs forward with little effect on total sales. Fourth, the degree of substitutability for coal would determine the ability of the firms to pass the costs on to customers over time. Fifth, economies of scale of cooperative control arrangements would reduce average cost of control for individual firms.

The reason these economic arguments are frequently ignored in discussions of acid drainage control, is that very little data are available to test their relevance. This study was directed toward the goal of collecting relevant data and applying economic analysis to the problem. The study was proposed in two phases, the first being concerned with the internal economic effects of water quality management to the firm and its competitors; the second dealing with the external costs and benefits that would accrue to the firm, its competitors, local communities and the state from alternative water quality programs. Therefore, the objectives of Phase I of the study were to:

(1) Measure the quantity and quality of acid mine drainage attributable to the current stripping operations of the company. Data were acquired directly from information compiled by the coal company over time and from State and Federal agencies concerned with rainfall, runoff, and water quality. These included the Federal and State Geological Survey Agencies, Ohio River Valley Water Sanitation Commission, Federal Water Quality Administration, U.S. Army Corps of Engineers, Ohio Reclamation Association, Ohio Health Department and the ranger of the U.S. Forest Service who is currently assigned to the area.

(2) Measure the current costs of controlling acid mine drainage from current stripping sites and to separate these costs from other reclamation costs of the firm. The data were developed from the coal company's records as

well as from information compiled in other studies concerning the costs of controlling mine drainage pollution such as those of Dean Charles Holland, and Professor Edward Moss of the School of Mines at West Virginia University, Professor Richard Tybout of Ohio State University, the Ohio Reclamation Association, and individual company estimates.

(3) Estimate the effect of these costs on the total costs of stripping coal for the firm and the ability of the firm to pass these costs on to customers or to landowners in the form of reduced mineral rights fees, or to absorb them and thus measure the effect on its competitive position of absorbing these costs. To do this, an attempt was made to estimate the demand curve and price elasticity of demand for the industry and firm.

(4) Estimate the costs and the effect of the costs associated with proposed alternative drainage control programs on the economic position of the firm in the market area where it operates.

Previous Studies

Previous studies on the economic costs associated with acid mine drainage are few. Brooks claimed that up to 1966

> . . . useful information on the cost of strip mining reclamation and control of acid

> drainage is not readily available. What has been published is often of little meaning because there is no indication of what is included in the cost figure.[5]

In their study, The Myles Job Mine, Brock and Brooks estimated costs of acid drainage control but made no attempt to measure all external costs associated with the Myles Job Mine, nor did they look at any historical data relating to acid drainage from the mine. They also attempted to estimate the net social benefit associated with surface mining in northern West Virginia.[6] Costs associated with reclamation are documented by several authors although the range of estimates is considerable.[7]

In one of the few economic studies on the subject of reclamation in general, Brooks recently concluded that the effects of more rigid reclamation laws in Kentucky were to reduce output in the short run for the coal industry of Kentucky and to result in greater concentration of production in the long run.[8] His actual results differ from our hypothetical results in terms

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[5] Op. cit., p. 26.

[6] Samuel M. Brock and David B. Brooks, The Myles Job Mine (Morgantown: Office of Research and Development, West Virginia University, 1966).

[7] Brooks, op. cit., p. 27.

[8] David B. Brooks, "Analysis: Surface Mine Regulation," Coal Mining and Processing, Vol. 7, No. 3 (March, 1970), pp. 38-41.

of short run effects but our long run projection agrees with the Brooks' conclusion. Our conclusions appear in Chapter VI.

To our knowledge no case studies such as this have been publicized. We hope that more will be done in the future since we believe that individual firm and sub-aggregate market analyses are needed to properly measure the possibility for and effects of water pollution control programs.

The Target Mine

The data for this study were generously provided by a coal stripping firm located in southeastern Ohio. Because of our promise not to identify the firm in any way, we were able to examine its books as well as other aspects of its operations. Since we have made a promise of confidentiality, we cannot report figures, locations and other information in a specific manner. Consequently, we have disguised some of the information and used proxy variables where we felt identification would be possible. These changes do not affect the results of our calculations nor do they change the conclusions of the study.

Chapter II of the study presents the geography and geology of the area surrounding the target mine, a discussion of the quantity of water in the area, and the results of our sampling of the streams in the area. Chapter III summarizes the costs associated with water treatment derived from other studies as well as some estimates of our own determined from other studies and discussions with many government officials and consultants dealing with water management problems. Chapter IV details the market structure in which the target mine operates and presents our estimates of its cost and demand functions. Chapter V shows the market adjustment that the firm must make to absorb alternative water management costs and the possible market effects this adjustment would have. We also illustrate the effect of additional reclamation costs which the firm is now or soon will experience. Chapter VI presents the summary and conclusions of our study as well as some generalizations derived from the analysis of the target mine which might be relevant to the water management problems facing firms of similar size or similar market circumstances.

CHAPTER II

LAND AND WATER IN TARGET MINE'S AREA

Geography and Geology of Target Area

The target mine is a small stripping company operating in a limited geographic region within Hocking and Perry Counties. Perry and Hocking counties are located in the hilly country of southeastern Ohio on the western edge of the Appalachian Coal Basin.

The economy of the region has a long history of dependence upon subsistence farming, coal mining and limited manufacturing of ceramic products associated with local clays. Per capita income and level of education are below the state average, and both counties have had general out-migration since the early part of this century. Of the existing population, many commute daily to jobs located as far away as Newark and Columbus, Ohio.

In the vicinity of the target mine the topography is sharply rugged with steep-walled valleys and narrow ridges. The slopes average 20-30 percent with upper limits of 50 percent. The mine operates in the Hocking River watershed along minor tributaries of Monday Creek.

Some of the streams in the immediate vicinity of the present stripping are intermittent.

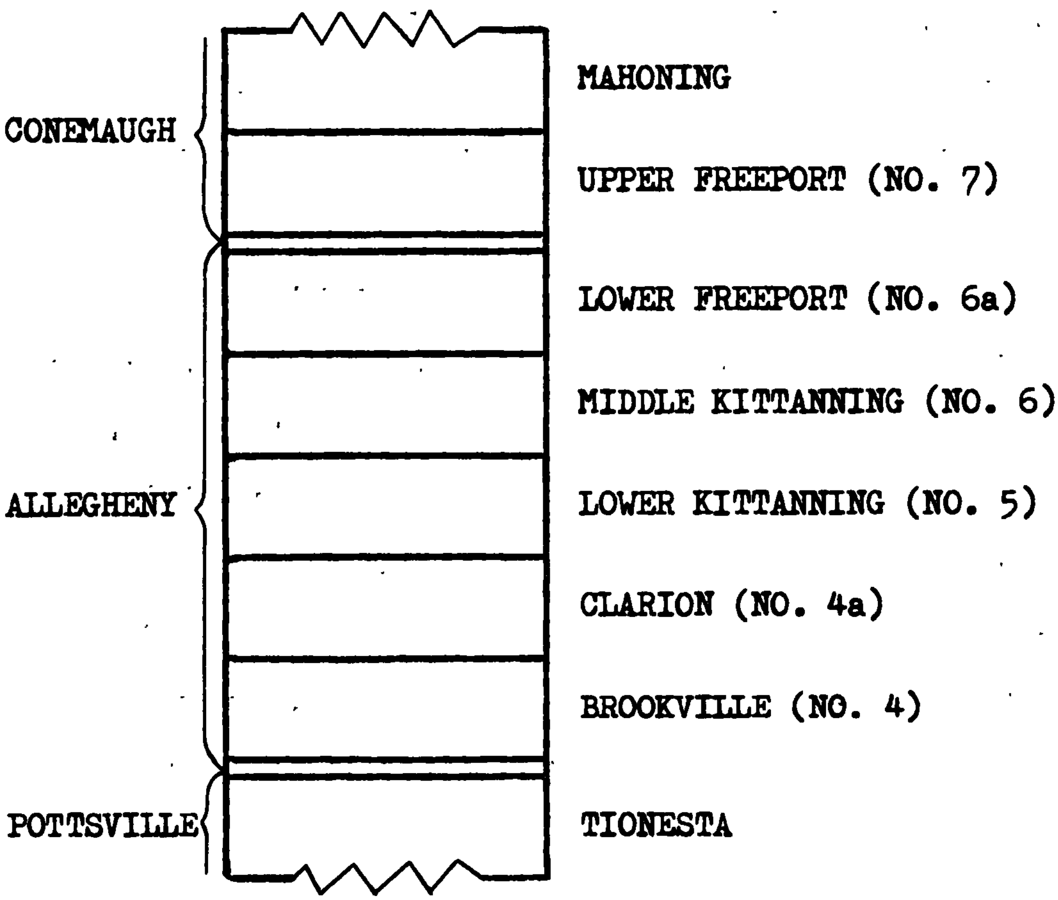
Much of the land in the area is within Wayne National Forest, and the hills and valleys are covered with a mixture of low grade second and third growth hardwoods and conifers. The mineral rights are often privately owned since the government acquired the surface rights without the subsurface rights. The assessed value of timber destroyed through mining must be paid to the government.

The rock strata are of the Allegheny Series of the Pennsylvanian System. Four different coal beds have been deep or strip mined in the area. They are the Lower Kittanning (No. 5), Middle Kittanning (No. 6), Lower Freeport (No. 6a), and the Upper Freeport (No. 7). (See Figure 1.) The coal beds are often characterized by shale and flinty partings. Pyritic material is present in the coal and adjacent shale in nodules and dispersed particles.

The No. 6 coal is the thickest bed in the area, generally about 4 feet. In the late 19th and early 20th centuries, the No. 6 coal was extensively deep mined and later the outcrop was stripped. The No. 5 coal is generally thin, ranging from 14 to 28 inches. At the mine site it is about 24 inches thick and has been subjected to limited stripping.

FIGURE 1

COAL BEARING STRATA IN VICINITY
OF TARGET MINE



Source: Russell H. Brant, "Geological Description and Effects of Strip Mining on Coal Overburden Material," The Ohio Journal of Science, 64(2): 68, March, 1964.

The No. 6a coal, which is currently being stripped by the target mine, occurs high on the narrow ridges, so the overburden is completely removed and all of the coal is taken. The coal is 24 to 30 inches thick with a shale parting, so the coal must be mined in two stages. The overburden and the upper layer of coal are removed. Then the parting is separated for future burial and the lower layer of coal is removed. The No. 7 coal is also high on the ridges, where present, and is removed in the same manner as the No. 6a. The seam's thickness varies from a few inches to 48 inches.

The interval between the coal beds consist of shale, clay, siltstone, and occasionally, a thin bed of limestone. The cyclothem from the No. 6a coal to the No. 7 seam includes pyritic black shale immediately above the No. 6a coal which grades into a lighter colored clayey shale. A massive siltstone bed is above the shale, which in turn is overlain by a thin, massive, fresh water limestone. A dark, pyritic underclay of the No. 7 coal is above the limestone bed.

As a broad generalization, the toxic materials necessary for forming acid mine drainage is intimately associated with the coal. The black shales immediately above and below the coal, especially the underclay, are pyritic and reactive.

The pH analysis of three spoil samples indicated rapid improvement of the material as the in-place distance from the coal increased. A sample of coal and immediately adjacent clay had a pH of 2.06. Recently exposed spoil, from which most of the black material had been separated, had a pH of 3.77. Spoil that had weathered for about three months had a pH of 4.12. A variety of grasses had already begun to volunteer on the latter spoil without any attempt at reclamation by the mining company.

Since there is little limestone in the area, the natural buffering action common to much of the eastern Ohio coal fields is largely lacking. Consequently, the water and spoil are locally quite toxic. However, the Forest Service has found that reclaimed spoil (which essentially means separation and burial of black materials and some grading) consistently has a pH of 4.5 or slightly above and it will support growth of acid loving conifers.[1/]

Water Quality

The Division of Engineering of the Ohio Department of Health found the following conditions at the mouth

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[1/] Conversation with Mr. Paul Braun, Forest Ranger, Wayne National Forest, Athens, Ohio office.

of Monday Creek in 1967. During the low flow period, the dissolved solids concentration was 1,560 mg/l. The pH index was 2.9, sulfate concentration was 1,070 mg/l, chlorides 45 mg/l and zero bicarbonates. Field surveys by the U.S. Forest Rangers in Wayne National Forest confirm the aforementioned findings and that the conditions prevail continuously and are of long duration.[2]

Lost Run Creek, a tributary of Monday Creek, runs through the property on which the target mine is presently operating. The stream's source is a mine tunnel leading into the No. 6 coal. Additionally, water seeps or flows from hundreds of mine openings, pits, and spoil banks to feed Lost Run upstream from the target mine. The stripping is "pre-law," so no reclamation has occurred. Vegetation has volunteered on portions of the disturbed areas, but in many areas the spoil banks remain bare and continuously eroding. Without an extensive and expensive remedial program, there is no hope that the heavy mineral and sediment load entering the area's streams will be reduced in the foreseeable future.

Table 1, Water Quality Data, lists some water quality characteristics of Monday Creek, Lost Run, disturbed

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[2] Correspondence with U.S. Army Corps of Engineers, Huntington District, Huntington, West Virginia.

TABLE 1

WATER QUALITY DATA, TARGET MINE AND LOST RUN CREEK

Location	Date	pH	Acidity (Mg/l)	Sulfate (Mg/l)	Total Iron (Mg/l)	Total Aluminum (Mg/l)	Total Manganese (Mg/l)
*Monday Creek near Lost Run[1]	1967	3.1 to 3.6	248.7	419	6.7	27.1	11.0
*Abandoned site near Lost Run	Summer 1970		1265	1500	420.0		
+Lost Run upstream of Target Mine	September 1970	4.00	850	1840	240.0	78.0	106.0
*Lost Run below Target Mine	October 1970	3.20	745	990	20.0	20.0	18.0
#Face of 6a coal at Target Mine	November 1970	2.95	907	1645	74.3	144.0	37.5
#High Level Pond at Target Mine	November 1970	3.09	930	2195	33.9	123.0	59.5
#Low Level Pond at Target Mine	November 1970	4.18	171	730	1.88	28.6	23.5
#Lost Run at point where Target water discharges	November 1970	3.08	360	568	26.3	42.6	18.0

TABLE 1--CONTINUED

Location	Date	pH	Acidity (Mg/l)	Sulfate (Mg/l)	Total Iron (Mg/l)	Total Aluminum (Mg/l)	Total Manganese (Mg/l)
#Stream near tipple carrying water from old stripping and deep mines	November 1970	3.26	283	538	8.9	33.8	17.5
#Lost Run below Target Mine	November 1970	3.18	280	600	20.2	36.2	16.5
#Stream from lower Pond	October 1970	3.50	355		2.0	59.0	
+Pond at pit of 6a coal seam	December 1970	4.05	895	1670	180.0	128.0	84.0
+High level pond at Target Mine	December 1970	3.90	1040	2045	162.0	145.0	143.0

[1]Averaged data from a series of samples taken during 1967 by the Federal Water Quality Administration.

Source: *, Federal Water Administration; #, West Virginia University Chemical Analysis; +, Papucci Testing Laboratories, Cincinnati, Ohio.

sites along Lost Run, and from the target mine. As the table indicates, the quality of the water coming from the mine is poor, but is not as bad as the quality of water in Lost Run.[3]

Throughout the past decade, field readings by U.S. Forest Service personnel and State officials have consistently recorded pH levels of about 3.0 for all instream waters in the vicinity of the target mine. Field readings by the authors during the fall of 1970 were in the same range.

Target Mine's Water Quality

The quality of mine drainage effluent from the target mine does not fit neatly into any of the classifications derived by the Federal Water Quality Administration (Chapter III, Table 4, page 35), but would be a mixture of Classes 1 and 2. The pH is generally below 3.0 (Class 1), but the other factors more closely fit Class 2. The acidity ranges from 170 to approximately 1000 mg/l, total iron ranges from 2.0 to 180 mg/l, aluminum ranges from 30.0 to 145 mg/l, manganese ranges from 20.0 to 145 mg/l, and sulfate content is 500 to 2000 mg/l.

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[3] The pH readings from the Papucci Testing Laboratories analyses were consistently higher than other sources. It is probable that the lower pH readings obtained by most samplers more nearly represent the continuing water quality conditions.

Water from the current mining activities can be separated into three different categories because most water goes through three different stages before entering the streams. Water trapped in the pits has a pH of 3.0 or below, acidity of about 900 mg/l, and relatively high levels of sulfate, iron, aluminum, and manganese.

Water from the pits then seeps, flows or is pumped over the hill to a series of ponds about fifty feet below the current stripping. The ponds were created by spoil from previous stripping operations, so the high level impoundments do not reflect deliberate planning. However, they act as silt basins and the pH, acidity, and mineralization contents improve somewhat relative to water in the pits (see Table 1). This is probably due to the natural buffering action of minerals in the spoil and dilution by non-acid water.

From the high level ponds water seeps and flows to a lower level pond formed by slippage of a spoil bank which blocks a narrow valley. The pond is elongated and retains run-off from disturbed and undisturbed areas. The low level pond is an effective silt retention structure and the acidity of the retained water is considerably improved. The pH is around 4.0 and the acidity (less than 200 mg/l) and iron (less than 10 mg/l) content are also greatly reduced.

Overflow from the low level pond forms the northerly flowing stream which enters Lost Run Creek upstream of the target mine's tipple. The water is free of sediment and the water quality measurements are better than those of the larger streams.

Ohio Water Quality Standards

Ohio water quality standards do not deal directly with quality and quantity of coal mine effluent. However, the Ohio Department of Health's Water Pollution Control Board under Sections 6111.01, 6111.03, 6111.31 to 6111.38, and 6111.99 of the Ohio Revised Code does have criteria for determining the quality of stream water that must be maintained for specific uses, such as municipal, industrial, recreational, aquatic life, and agricultural purposes. Section 6111.03 as amended on April 14, 1970, provides standards which may be utilized to prevent mine drainage pollution.

Under the heading "Minimum Conditions Applicable to All Waters at All Places and at All Times," the Revised Code states that waters must remain:

1. Free from substances attributable to municipal, industrial or other discharges, or agricultural practices that will settle to form putrescent or otherwise objectionable sludge deposits.
2. Free from floating debris, oil, scum and other floating materials attributable to municipal, industrial or other discharges,

or agricultural practices in amounts sufficient to be unsightly or deleterious.

3. Free from materials attributable to municipal, industrial or other discharges, or agricultural practices producing color, odor or other conditions in such degree as to create a nuisance.
4. Free from substances attributable to municipal, industrial or other discharges, or agricultural practices in concentrations or combinations which are toxic or harmful to human, animal, plant or aquatic life.

The Revised Code further states that no water which presently exceeds minimum standards established for specific uses shall have its quality reduced. Of the specific minimum standards established for various water uses, those provided for aquatic life are most appropriate for the study area because it is primarily national forest and sparsely populated. The dissolved oxygen must average 5.0 mg/l per calendar day and not less than 4.0 mg/l at any time. The pH values must range between 6.0 and 8.5, except for fluctuations associated with photosynthetic activity.

However, within the Hocking River Basin, Rush Creek, Monday Creek, Sunday Creek, Federal Creek, and those minor tributaries polluted by acid mine drainage from underground mines and pre-reclamation law strip mines are exempt from current Ohio water quality legislation, except that no further degradation of stream quality from mining is permitted.[4]

Water Quantity

Monday Creek is the largest stream in the area in which the target mine operates. In 1967 the Federal Water Quality Administration measured the flow in Monday Creek downstream from the mouth of a tributary that runs through the target mine's property. The average flow was 7.6 cfs with a maximum of 15.0 cfs.[5] No other records were found on flow measurements in the vicinity of the mine.

Lost Run, the tributary flowing through the target mine's property, originates in the tunnels of abandoned deep mines of the No. 6 coal seam about two miles upstream of the target area. Two other small streams, one with a northerly flow and the other flowing in a southerly direction empty into Lost Run on

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[4]Water Pollution Control Board, Department of Health, Water Quality Standards Adopted by the Board December 9, 1969 (Amended April 14, 1970) for the Hocking River Basin, Columbus, Ohio, p. 2, paragraph 4.

[5]U.S. Department of the Interior, "Stream Pollution by Coal Mine Drainage in Appalachia," Attachment A to Appendix C of Appalachian Regional Commission's report, Acid Mine Drainage in Appalachia, 1969, p. 159.

the mine property. Each stream drains areas previously or presently being mined. Both streams are said to be intermittent. However, during the months of August to December, 1970, there was some flow in each stream.

It had been anticipated that the quantity of water would be available from indirect sources. The limited duration of the study precluded any meaningful analysis through direct measurements. Unfortunately, no evidence was found of any previous records being made of stream flow on Lost Run or its tributaries.

On October 8, 1970, Federal Water Quality personnel attempted two measurements in Lost Run, but the low flow makes the results somewhat suspect. One measurement was taken in Lost Run immediately downstream from the confluence of the northerly flowing tributary. The reading was 0.16 cfs, or 72 gpm. The flow in the tributary was estimated to be approximately 15-20 gpm.

A second reading was taken on Lost Run downstream of both tributaries. The flow was 0.17 cfs, or 76.5 gpm. The flow in the downstream tributary was estimated to be 20-25 gpm.

The rainfall in the area averages about 40 inches per year. The current mining of the target company is near the top of the ridges, so there is relatively little water directly associated with the stripping. During two heavy rains that we observed, sheet wash was not extensive. Apparently the spoil banks and ponds absorbed much of the water and retarded run-off.

No hydrographic studies were attempted, but the volume of water being carried by Lost Run was not drastically increased after the storms. Where the grade of the stream is low, the channel is ill defined because of the sediment load, so over-bank flows at those points occur readily. Sediment sources are numerous and plentiful in quantity because of previous mining activities. However, the target mine does not appear to be a significant contributor because the ponds on the site act as effective silt basins.

According to the Hydrology Division of the U.S. Army, Corps of Engineers, Huntington District, the conditions present in the Monday Creek portion of the Hocking River Basin leads to average annual run-off of 0.00134 cfs/acre. The run-off is based upon 40 inches average annual rainfall and given soil and vegetative conditions. The 0.00134 cfs per acre is equivalent to 868.32 gallons per day per acre or 316,936.8 gallons per year per acre of run-off.

Since the total run-off from an average acre of land is only 29.2 percent of the annual rainfall, these figures are not representative of the run-off conditions from recently stripped acreage. Studies by the U.S. Forest Service of three disturbed watersheds in eastern

Kentucky showed the run-off to be about 50 percent for the 1968 water year.[6] Assuming the higher run-off rate, an average yield per acre per annum would be 543,124 gallons.

To get a better measure of short term quantities of water the company might be forced to handle, it is assumed that a 24-hour storm with a 10-year frequency results in 3.8 inches of rainfall on land where the antecedent conditions are normal.[7] The vegetative cover will have been completely removed, so it is further assumed that the run-off rate would be slightly greater than would occur with row crops of similar soil characteristics but less than the run-off from a paved surface. The run-off from an acre of land meeting the above criteria would be 81,463 gallons.[8]

In the vicinity of the target mine, the water problems are greatly complicated if coal is stripped from any seams lower than the No. 7 or No. 6a. As already

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[6] Conversation with Mr. Willie Curtis, Hydrologist, U.S. Forest Service, Berea, Kentucky.

[7] U.S. Weather Bureau Technical Paper No. 40, Rainfall Frequency Atlas of the U.S. for Duration from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years.

[8] The criteria for measuring storm run-off are developed by Ven Te Chow, editor, Handbook of Applied Hydrology, McGraw-Hill Book Co., New York, N.Y., Chapter 21.

mentioned, the No. 6 seam has been extensively deep mined and the maze of tunnels have become channels for good-sized streams surfacing at points where tunnels were cut into the No. 6 coal outcrop along the hillsides. Stripping the outcrop may result in additional breakthroughs into the rooms and tunnels of the abandoned deep mines. Acid water then flows or seeps from the deep mines into the strip pits, creating expensive handling problems.

An even more complicated problem for the target mine existed in 1968 and 1969 when it stripped 12.5 tons of coal from the No. 5 seam. The No. 5 seam is about 20 feet below the No. 6 coal which had previously been deep mined and then the outcrop was stripped until numerous breaks into the deep mine had occurred.

The target mine stripped the overburden from the No. 5 coal until only a narrow ledge was left from the earlier No. 6 stripping. The water coming into the No. 5 strip pits was from rainfall as well as flows or seeps from the bench of the No. 6 stripping. Much of the water coming off the bench appeared to flow from the breaks in the highwall leading into the deep mine.

During periods of little rainfall the water entering the No. 5 strip pit was limited to seeps whose contribution to any water already in the pit was minimal. However, during and after heavy rains the volume of water coming down the highwall was plentiful and sustained. No quantitative measures of the marginal contribution of water from the previously mined area to the total volume of water per unit area of No. 5 stripping were attempted, but the extra water was significant, possibly doubling the water that would have to be treated.

Since the area disturbed was less than an acre, the total volume of water was limited. Mining under such conditions should not be attempted unless the per acre coal yield is profitable enough to offset greatly increased treatment costs.

CHAPTER III

PREVENTION OF ACID MINE DRAINAGE AND RECLAMATION

General Techniques and Costs of Preventing or Abating Mine Drainage Pollution and Reclamation Programs

In all cases the mine operator should preplan the stripping operations so that acid mine drainage and sedimentation are kept to a minimum. Since acid will form on exposure to moist air, there is little that the miner can do to prevent acid formation if pyritic material is present. However, the acid becomes a problem when it gets into the streams and impoundments of the area. Therefore, whenever possible, water should be diverted around or directly through a disturbed area. This may be partially accomplished by utilizing diversion ditches, flumes, and pipes.

Although it does not always occur, the pyritic material is usually intimately associated with the coal seam. Those strata immediately above and below the coal tend to be toxic and should be segregated from the overburden and buried as quickly as possible to minimize their contact with air and flowing water. Whenever possible the toxic material should be buried in such a manner that it becomes inundated by water. This may be accomplished by placing the toxic material in low spots with relatively impervious underlying strata so that water becomes ponded under the overburden material. Inundation may also be accomplished by causing infiltration into the overburden so that the ground water table within the spoil is consistently above the toxic wastes.

Successfully segregating and timely burial of toxic material should reduce the cost of pollution control in all aspects of strip mining. Burying the toxic material necessitates reworking of the spoil banks which, when done carefully, should reduce hydraulic erosion and permit early planting in order to re-establish a vegetation cover. With little or no extra effort the shovel operators can separate the overburden initially so that the bulldozers can then shove the overburden back into the pit and over the toxic material in such a way that the spoil material most capable of quickly supporting plants is on top. In all cases the movement and grading of the spoil should be kept to a minimum in order to keep down earth moving costs and to avoid excessive compaction. Compaction of the spoil reduces plant supporting capacity and increases erosion through prevention of infiltration.[1/]

[1/] For an expanded discussion of water handling and refuse disposal the reader is referred to <u>Principles, Practices and Case Histories in the Control of Acid Mine-Drainage</u>, by Coal Industry Advising Committee of the Ohio River Valley Water Sanitation Commission, March, 1964. Many of the case studies are post-1964.

Since it is practically impossible to keep all water out of the pit and out of contact with toxic material during active mining, plans must be developed to deal with the water so that the area's streams do not become polluted by acid and sediments. There are numerous techniques available that singly or in various combinations are capable of abating potential pollution problems. One of the most exhaustive studies available concerning techniques, their costs and state of development was compiled by Cyprus Wm. Rice and Company of Pittsburgh, Pennsylvania in 1969.[2/]

Tables 2, 3, and 4 show potential methods for controlling mine drainage pollution and mine drainage classifications. Table 2 lists the 11 techniques that are most highly developed in the sense that they have been placed in use by mining companies or that experimentation has proceeded to the point that some measure of cost could be obtained. Table 3 lists 12 techniques whose future prospects for controlling mine drainage pollution may be good, but their present state of

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[2/] "Engineering Economic Study of Mine Drainage Control Techniques," by Cyrus Wm. Rice and Company is published as Appendix B to Acid Mine Drainage in Appalachia by the Appalachian Regional Commission, Washington, D.C., 1969. Appendix C of the same study, "The Incidence and Formation of Mine Drainage Pollution" by the Office of Appalachian Studies and the Department of the Interior presents an excellent discussion of the complex nature of the chemistry of acid mine drainage and Attachment E to Appendix C provides a survey of costs of methods of controlling acid mine drainage.

TABLE 2

CONTROL TECHNIQUES IN CATEGORY A

Technique	Application	Effluent Quality, ppm (1)				Cost $/M Gals. Mine Drainage (1)
		pH	TDS	Hardness	Fe	
Neutralization	A,B,S,D,1,2	7-8	500-3000	500-3000	1	0.19 - 0.28
Reverse Osmosis (2)	A,B,S,D,1,3	4-5	10-20	1	0.1	0.30 - 0.50
Stream Flow Regulation (3)	A,B,S,D,1,2,3,4	6-7	700-500	100-200	1-50	0.30 - 0.71
Deep Well Disposal (4, 8)	A,B,S,D,1,2,3,4	N.A.	N.A.	N.A.	N.A.	0.41 - 0.55
Surface Reclamation	A,B,S,1,2,3,4	(6)	(6)	(6)	(6)	N.A.
Revegetation (8)	A,B,S,1,2,3,4	(6)	(6)	(6)	(6)	N.A.
Pumping and Drainage	A,B,S,D,1,2,3,4	N.A.	N.A.	N.A.	N.A.	0.02 - 0.05
Water Diversion	A,B,S,D,1,2,3,4	(6)	(6)	(6)	(6)	N.A.
Mine Entry Sealing (5)	B,D,1,2,3,4	(7)	(7)	(7)	(7)	0.04 - 0.40
Refuse Treatment	A,B,S,D,1,2,3,4	(6)	(6)	(6)	(6)	N.A.
Impoundment	A,S,1,2,3,4	(6)	(6)	(6)	(6)	N.A.

TABLE 2--CONTINUED

(1) Factors based on moderate acidity (1500 ppm) and 10 mgd of mine drainage
(2) With deep well injection
(3) Single purpose reservoirs system, 10:1 - 20:1 dilutions
(4) 1.0 mgd well capacity
(5) Hydraulic sealing to abate 0.3 - 3.0 mgd
(6) Uncontaminated surface water quality
(7) Uncontaminated ground water quality
(8) A supporting, not a primary, technique

A - active
B - abandoned
S - surface mine
D - deep mine
N.A. - not applicable
1,2,3,4 - category of mine drainage

Source: Cyrus Wm. Rice, ibid., p. 5.

TABLE 3

CONTROL TECHNIQUES IN CATEGORY B

Rank (1)	Technique	Application		
		Surface	Deep	Mine Drainage Category
1	Desulphating	ACT, ABD	ACT, ABD	3
2	Inert Gas Blanket	--- ---	ACT, ABD	1, 2, 3, 4
3	Grouting and Sealing	--- ---	ACT, ABD	1, 2, 3, 4
4	Microbiological Iron and Sulphur Removal	ACT, ABD	ACT, ABD	1, 2, 3, 4
5	Sulfide Iron Removal	ACT, ABD	ACT, ABD	1, 2, 4
6	Ion Exchange	ACT, ABD	ACT, ABD	3
7	Electrodialysis	ACT, ABD	ACT, ABD	3
8	Evaporation	ACT, ABD	ACT, ABD	3
9	Sterilization	--- ---	ACT, ABD	1, 2, 3, 4
10	Microbiological Control	--- ---	ABD	1, 2, 3, 4
11	Internal Sealing	--- ---	ACT	1, 2, 3, 4
12	Permanganate Iron Removal	ACT, ABD	ACT, ABD	1, 2, 4

(1) Ranked on the basis of promise of successful application.

ACT - Active Mines
ABD - Abandoned Mines

Source: Cyrus Wm. Rice, *ibid.*, p. 6.

TABLE 4

MINE DRAINAGE CLASSIFICATION*

	Class 1 Acid Discharges	Class 2 Partially Oxidized and/or Neutralized	Class 3 Oxidized and Neutralized and/or Alkaline	Class 4 Neutralized and Not Oxidized
pH	<3.5	3.5 - 6.5	>6.5	>6.5
Acidity,** Mg/l ($CaCO_3$)	1,000 - 10,000	(-50) - 1,000	>(0)	>(0)
Ferrous Iron, Mg/l	500 - 10,000	0 - 500	0	50 - 1,000
Ferric Iron, Mg/l	0	0 - 1,000	0	0
Aluminum, Mg/l	0 - 100	0 - 20	0	0
Sulfate, Mg/l	500 - 10,000	500 - 10,000	500 - 10,000	500 - 10,000

*Derived by FWPCA as a useful approximation.
**A negative acidity indicates alkalinity.

Source: Cyrus Wm. Rice, *ibid.*, p. 7.

development is too experimental to permit any generalizations about the cost per unit of water treated. Table 4 separates mine drainage into four classifications according to the severity of the pollution problem with which the miner must deal.

All control techniques involve considerable expense and none are without defects. Neutralization increases the hardness of water and produces a sludge that presents expensive disposal problems.[3/] Reverse osmosis cannot deal with water containing sediments because the membranes become fouled. Stream flow regulation to utilize the natural alkalinity of unpolluted water to neutralize the acid from mine discharge requires alkaline streams having flow rates great enough to neutralize the acidity and the polluted discharges. The technique is effective where the necessary conditions prevail, but it lacks universal applicability. Deep well disposal of water or sludge also has serious limitations because the necessary geologic formations are not always available. Successful deep well injection requires a permeable formation surrounded by impervious formations. Because of imperfect subsurface geologic knowledge there is the possibility of serious pollution problems being created

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[3/] The College of Mines at West Virginia University currently has a research contract to attempt to solve this very difficult problem.

by migration of acid water through the substrata.

Water handling by pumping or diversion also has limitations. Pumping must be regulated to avoid slugging the receiving stream with too much low quality water. Pumps are also susceptible to fouling, so supervision is necessary. Diversion can be difficult in certain terrain or when the area involved is quite large.

The degree of success that can be expected, especially in the short run, from reclamation, including revegetation and ponding, is highly variable. Spoil characteristics may be such that they will readily support vegetation and in other cases the spoil will be highly toxic and will weather slowly. Ponding to inundate toxic material and to trap sediment may be limited by legal or geologic conditions.

Neutralizing Acid Water

Neutralization is the treatment process with which the coal mine industry has had the most experience and, therefore, more data are readily available concerning costs, successes, and problems associated with neutralization compared with other processes.[4/] Mine drainage often contains sulfuric acid, ferrous sulfate,

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[4/] See Cyrus Wm. Rice and Company, ibid., p. 17 ff. for a detailed discussion of this topic.

and salts of calcium, magnesium, and aluminum. Acid conditions may be treated by various alkalis, such as soda ash, caustic soda, lime, and limestone.

Treatment of mine water effluent with an alkali is only utilized when the mine drainage fits Classes 1 and 2 of Table 4 because Classes 3 and 4 do not present acidity problems. However, Class 4 may require lime treatment when the water has a high ferrous iron content. The treatment process eliminates the acidity, greatly reduces the iron and aluminum and the calcium sulfate, but hardness is increased.

Because of lower cost and ready availability, lime and limestone are the only two alkalis used by mining companies for treating their effluent. Lime is still the most widely used agent, but limestone's lower cost and simpler application has increased its use. However, limestone's efficiency in raising the pH without aeration is considerably less than that of lime.

Capital costs for either alkali are approximately the same, except that the water content of the sludge is much less for limestone than for lime, so the capacity of settling basins utilizing limestone would not have to be as great as would be the case with lime. Operating costs are somewhat less when using limestone instead of lime. This is largely because of the lower chemical cost.

Costs are a function of the quality of the effluent and the size of the operation. Most published cost figures involve plants with a capacity of at least 200,000 gallons per day. As Figure 2 shows, the operating cost declines significantly up to about 3 million gallons per day where the curve becomes relatively flat.[5] It is unfortunate that average operating costs are not available at smaller scales because useful information would have been provided about economies of scale. As an example, it would be most informative to know what happens to the Rice curve below 200,000 gallons. If it rises steeply, the small firm is at a decided disadvantage.

Operation Yellowboy is a mobile neutralization plant sponsored by the Coal Research Board of the Commonwealth of Pennsylvania. In the mid sixties preliminary capital and operating costs were ascertained for six different sites requiring different capacities and handling a variety of water qualities. The facility includes a centrifuge for mechanically dewatering the sludge which is then ready for disposal. The cost of sludge handling is included in Table 5 which lists the cost of operating the plant at each of the test sites.

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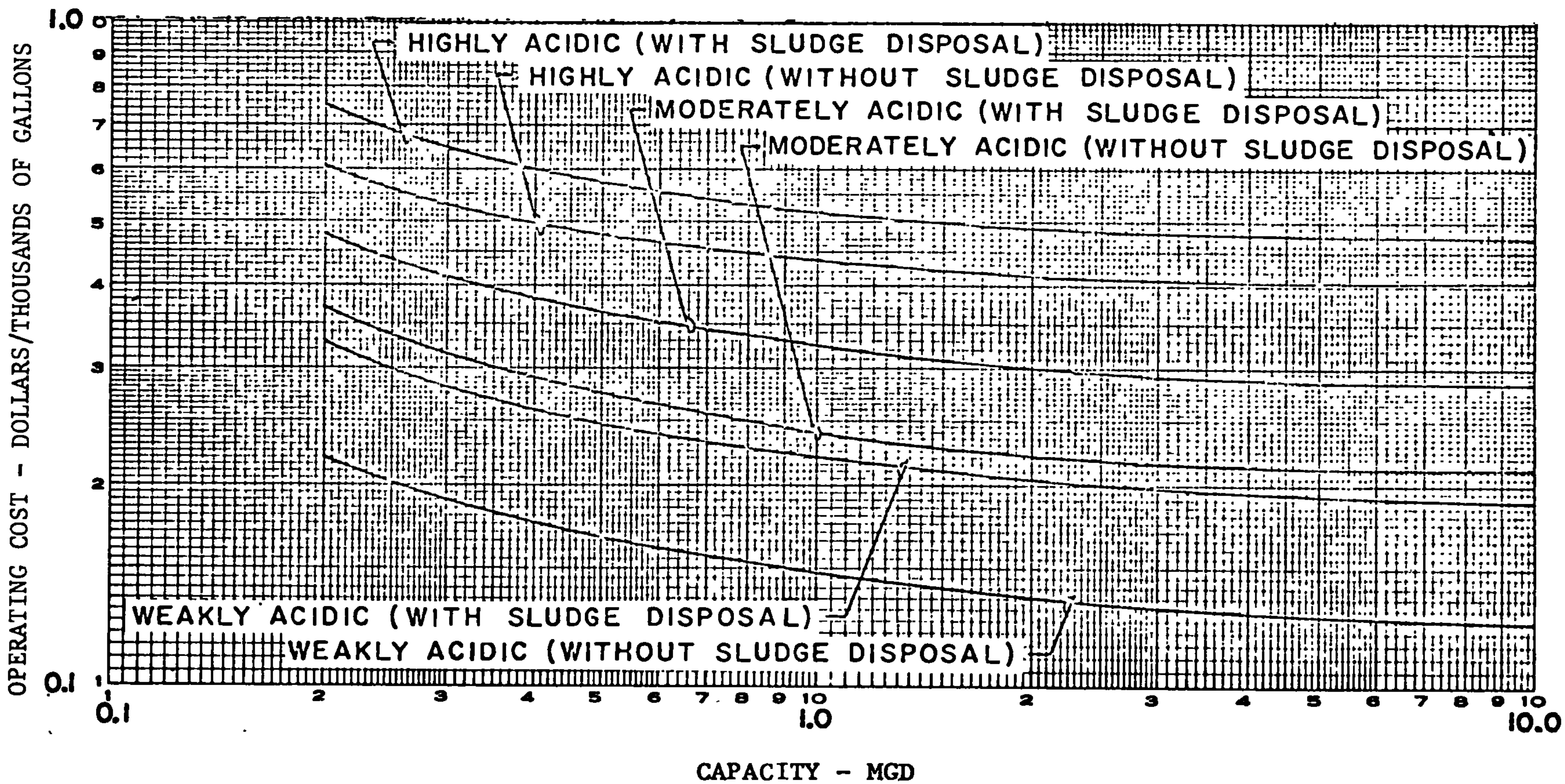
[5] Cyrus Wm. Rice and Company, ibid., p. 37.

FIGURE 2

TOTAL OPERATING COST (INCLUDING CAPITAL COSTS)
HYDRATED LIME TREATMENT
REF. #80

LEGEND:

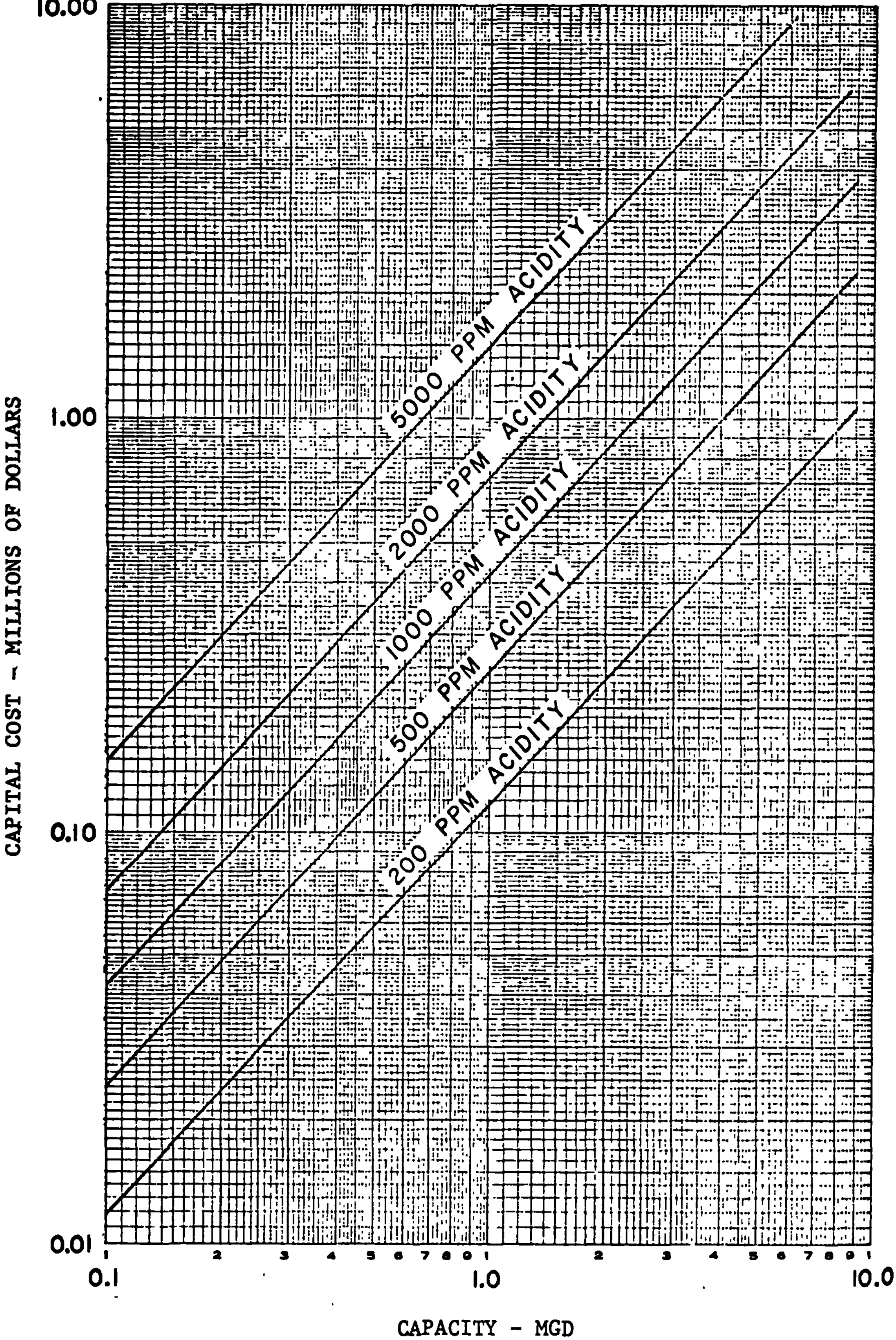
	IRON - PPM	ACIDITY - PPM
HIGHLY ACIDIC	600 - 1200	2800 - 4800
MODERATELY ACIDIC	600 - 700	1400
WEAKLY ACIDIC	322	600 - 700



SOURCE: Cyrus Wm. Rice, *ibid.*, p. 37.

FIGURE 3

CAPITAL COST VS. CAPACITY
HYDRATED LIME TREATMENT PLANT WITH SLUDGE DISPOSAL
(BASED ON OPERATION YELLOWBOY - REF. #28)



SOURCE: Cyrus Wm. Rice, ibid., p. 36.

TABLE 5

PRELIMINARY CAPITAL INVESTMENT-OPERATING COSTS FOR ACID MINE WATER TREATMENT USING OPERATION YELLOWBOY[1]

Item	Marianna #58		Little Scrubgrass		Young and Son	
	Raw	Treated	Raw	Treated	Raw	Treated
Flow rate - MGD	0.240		4.15		0.180	
pH	2.64	7.6	3.65	-------	2.60	7.1
Total iron - ppm	815.00	5.8	1.30	-------	225.00	2.4
Sulfate - ppm as SO4	10,000.00	6,180.0	301.00	-------	1,360.00	1,530.0
Dissolved solids - ppm	18,300.00	12,200.0	-------	-------	1,920.00	2,040.0
Estimated construction costs of required facilities	$347,200.00		$ 9,850.00		$229,900.00	
Fixed costs attributable to construction costs	[2]$ 25,550.00		[4]$ 2,275.00		[2]$ 16,900.00	
Operating and administrative costs						
Supervision and labor	36,500.00		730.00		20,000.00	
Power	4,700.00		7,045.00		3,200.00	
Chemicals (lime)	22,000.00		87.00		2,300.00	
Maintenance, repairs, miscellaneous and contingencies	6,500.00		99.00		5,000.00	
TOTAL	$69,700.00		$7,961.00		$30,500.00	

TABLE 5--CONTINUED

Item	Marianna #58		Little Scrubgrass		Young and Son	
	Raw	Treated	Raw	Treated	Raw	Treated
Total annual costs	[3] $ 95,250.00		[5] $10,236.00		[3] $ 47,400.00	
Total operating costs per 1,000 gal. of acid mine drainage		$1.09		$0.007		$0.721
Sludge - dry, tons per day[6]		12.50		------		0.69
CaO, tons per day		2.08		------		0.31

Item	Morea Strip Pit		Loomis #4 Shaft		Warwick	
	Raw	Treated	Raw	Treated	Raw	Treated
Flow rate - MGD	4.00		5.76		0.60	
pH	3.20	6.5	3.20	7.4	2.78	7.57
Total iron - ppm[4]	5.80	-----	360.00	6.4	712.00	2.60
Sulfate - ppm as SO_4	290.00	370.0	3,430.00	3,240.0	5,656.00	3,740.00
Dissolved solids - ppm	560.00	680.0	6,100.00	5,500.0	9,080.00	5,830.00
Estimated construction costs of required facilities	$657,400.00		$1,094,000.00		$282,700.00	

TABLE 5--CONTINUED

Item	Morea Strip Pit		Loomis #4 Shaft		Warwick	
	Raw	Treated	Raw	Treated	Raw	Treated
Fixed costs attributable to construction costs		[2]$ 48,371.00		[2]$ 80,500.00		[2]$ 22,000.00
Operating and administrative costs						
Supervision and labor		42,500.00		108,000.00		43,000.00
Power		8,700.00		100,000.00		15,000.00
Chemicals (lime)		20,000.00		152,000.00		29,000.00
Maintenance, repairs, miscellaneous and contingencies		7,000.00		35,000.00		8,500.00
TOTAL		$ 78,200.00		$ 395,000.00		$ 95,500.00
Total annual costs		[3]$126,571.00		[3]$ 475,500.00		[3]$117,500.00
Total operating costs per 1,000 gal. of acid mine drainage		$0.087		$0.226		$0.537
Sludge - dry, tons per day[6]		2.17		21.6		16.5
CaO, tons per day		2.23		10.0		NA

[1]All data from report by Dorr-Oliver Inc., titled "Operation Yellowboy" to the Pennsylvania Coal Research Board, The Department of Mines and Mineral Industries, Harrisburg, Pa., June 1966.

TABLE 5--CONTINUED

2/ 20 year amortization at 4% interest.

3/ Operating 365 days per year.

4/ 5 year amortization at 5% interest.

5/ based on 1 man - 1/2 day per week for high flow and 1/2 day every other week for low flow.

6/ Sludge resulting from acid mine drainage oxidation, neutralization, precipitation.

Source: Appendix C, Attachment E, Acid Mine Drainage in Appalachia, op. cit., p. 7.

Utilizing Operation Yellowboy and data from mining company operations, Brock and Brooks found that average treatment cost is between \$0.05 and \$0.10 per ton of coal.[6]

Reclamation Programs

Land reclamation costs are even more variable (when measurable) and difficult to interpret than are water treatment costs. Separation of the processes of reclamation and water treatment is somewhat arbitrary because some measures taken to prevent water pollution may facilitate or involve reclamation, and reclamation should always reduce water pollution.

The variability of per acre reclamation costs depends on the terrain, soil type, amount of acreage, equipment used, legislative requirements, age of the spoil, and degree of reclamation. Degree of reclamation probably creates the greatest cost differences for the company carrying out a program of reclaiming land during and immediately after removing the coal. Much of the earth moving is generally associated with filling in the last

[6] Samuel M. Brock and David B. Brooks, The Myles Job Mine (Morgantown, W.Va.: Office of Research and Development, Appalachian Center, West Virginia University, April 1968), p. 35. Most of these costs have risen since the original experiments were completed. Several indexes of costs are available but simply using the Wholesale Price Index suggests increases of 17% since 1965.

cut, so large acreages involving several cuts can be reclaimed at a lower cost per acre than when only a limited number of cuts are made before the high wall becomes too thick to economically continue the stripping.

The reclamation program depends upon state laws and expected future land use.[7] If the law or future use requires blasting the high wall to a low angle and backfilling to establish the original contour, the cost will be high. David Brooks found that estimates ranged from $50.00 to $3,000.00 per acre in the early sixties, with the $50.00 to $250.00 range being the most common in relatively level land.

In the Myles Job Mine study it was estimated that the reclamation cost per acre on 11.6 acres of land ranged from $250.00 to $460.00, depending on the technique utilized.[8] The low cost method involved backfilling of spoil into the final cut until the graded surface sloped away from the high wall at an angle of 3 degrees. The $460.00 cost per acre involved blasting the highwall to a 45 degree angle and backfilling until the original slope was re-established.

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[7] These laws are summarized in Appendix 1.

[8] Brock and Brooks, op. cit., p. 32.

In 1964 the Department of Interior did a state by state study of reclamation cost on land disturbed by strip mining in Appalachia.[9] It found the average cost of "complete" reclamation in Ohio to be $265.00 per acre. Assuming a cost increase of five percent per year, the 1970 average cost would have been approximately $350.00 per acre. The cost varied from one state to another, with Pennsylvania having the highest per acre cost of $361.00 in 1964. Cost differences are partially the result of differences in state laws. Pennsylvania's reclamation requirements are quite rigorous as indicated in Appendix 1.

In 1965 the Ohio reclamation law required mining companies to be licensed by the Division of Reclamation. The bond is now $300.00 per acre with a minimum of $2,000.00. Disturbed land must be graded to rolling topography to reduce erosion and to permit logging or grazing. Isolated peaks must be graded and ponding is permitted by building an earth dam in the final cut. Reclamation must be completed two years after completion of stripping. All toxic material must be separated and inundated with water or buried under spoil. Bond is

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[9] Robert W. Stephen and Walter C. Lorenz, "Survey of Costs on Methods for Control of Acid Mine Drainage Pollution," Acid Mine Drainage in Appalachia, Attachment E to Appendix C (Appalachian Regional Commission, 1969), p. C-E-25.

returned upon the approval of the Division of Reclamation.[10]

Federal reclamation requirements in Wayne National Forest of eastern Ohio are somewhat similar to Ohio's law. All toxic material must be separated and buried. Backfilling to cover the pit and coal seam to a depth of 3 to 5 feet is required. Spoil peaks must be graded and reclamation must be timely. A $200.00 bond is required per acre. The Forest Service does its own planting and returns $150.00 to the miner upon compliance with the law. The $50.00 fee is to cover planting and survey costs.

Ponding of water in the final cut is generally not permitted on Federal property. However, where the water is alkaline and ponding will enhance the recreational attributes of the area, impoundments may be created with an earth dam.

The U.S. Forest Service also requires a per acre payment for the value of timber destroyed by the mining process. The mining company then has the right to harvest the timber and sell it for whatever the market price will actually provide. The target mine has had to pay an average of $100.00 per acre for timber on disturbed Federal property.

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[10] U.S. Department of Agriculture, Restoring Surface-Mined Land, Miscellaneous Publication No. 1082 (Washington, D.C.: U.S. Government Printing Office, April 1968), pp. 12-15.

Techniques and Costs of Mine Drainage Prevention and Abatement Programs Usable by Target Mine

There are several general observations that ought to be clearly made when discussing the ability of small strip mining companies to carry out water pollution prevention or abatement and reclamation programs. Small mining companies are faced with technical and economic considerations that are not present for large companies, at least not in the same relative magnitudes. Probably one of the most important constraints placed on small companies is the lack of managerial skill and technical knowledge needed to preplan and manage a program that gives low cost water handling and effective reclamation. Large firms can hire specialists on a full and part time basis to analyze their problems and supervise effective programs to alleviate the situation. Large companies also appear to make better use of information and services made available by public agencies. This is undoubtedly due in part to the higher level of awareness of all opportunities on the part of successful managers of large firms, but there may also be an additional element that causes small firms which are owned and managed by a single or small group of individuals to avoid excessive contact with public officials.

In this chapter, four methods which the target mine might use in treating water before allowing it to enter the surrounding streams are discussed. Since all of these methods are hypothetical at this time, no attempt will be made to analyze their relative effectiveness. It is assumed that each method will achieve the goal of improving the pH and reducing mineralization to meet Ohio water quality standards. Where appropriate, obvious problems of a given method are discussed. A comparative effectiveness study would be most useful but is beyond the scope of this study.

Water Treatment Facilities

Water treatment facilities, as a general rule, require large capital outlays as well as skilled operators and involve economies of scale. Neutralization plants are particularly effective for large deep mines that have relatively controlled water sources and work the same site for many years. Acidity of the mine drainage is not generally as much of a problem for strip mines but the difficulties of trapping and treating the water are greater because of the magnitude of the surface area involved.

The target mine disturbs only 10 to 15 acres of land per year and it is continuously moving, so a neutralization facility would have to be small and mobile. Assuming that all run-off water from an acre of land could be trapped for treatment, an upper limit of approximately 543,000 gallons per annum could be expected, or 1,488 gallons per day. If 10 acres of land are involved, the annual volume of water would be 5,430,000 gallons, or 14,880 gallons per day.[11/]

Since a treatment facility would be forced to have a capacity greater than the average daily run-off, let us assume capacity large enough to handle the run-off from a 24-hour storm with a 10 year frequency. Ten acres of land could be expected to yield 814,628 gallons of water from such a storm. Using Figure 3, the capital cost of such a structure, considering the water quality at the target mine, would have been approximately $340,000 in 1965. A capital outlay of this magnitude by such a small firm is unrealistic.

Had the company acquired a sophisticated water treatment plant utilizing hydrated lime and including sludge disposal capable of treating 200,000 gallons per day of water containing 1000 ppm acidity, its capital cost in the mid-sixties would have been $84,000 (Figure 3). Using only a five percent per year rate of price increase would have resulted in a 1970 capital cost of approximately $107,217.[12/] Utilizing the operating cost

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[11/] See Chapter II, pp. 24-26.

[12/] Data for total cost of Figure 3 were developed from Operation Yellowboy experiments.

curve entitled "Moderately Acidic (with Sludge Disposal)" in Figure 2, the total operating costs (including capital costs) were $0.48 per thousand gallons of water treated in 1968.[13] Inflating $0.48 by five percent, the 1970 operating cost per thousand gallons would have been $0.53.

Such a treatment facility, referred to as Method 4 throughout the rest of this paper, would have cost the company $0.09 per ton of coal in 1970. The cost per ton was derived by assuming that 5,430,000 gallons of water would have been treated from 10 acres of disturbed land, yielding 32,000 tons of coal.

This treatment method is somewhat inappropriate for small mines for several important reasons. The initial capital outlay would discourage capital-short small firms. The facility would probably prove inflexible for contour stripping. The very sophistication of the plant would require considerable attention and training, unnecessarily complicating the operation of small firms.

To attempt to take a simpler approach such as retaining water temporarily within the pits in relatively small ponds and using a small daily capacity treating

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[13] Data for Figure 2 were obtained from C. T. Holland, et. al.,"Factors in the Design of an Acid Mine Drainage Treatment Plant," Second Symposium on Coal Mine Drainage Research, Pittsburgh, Pa., 1968.

facility that is highly mobile would probably be fairly effective. A device such as this might involve a pump bringing water to a flume over which a hopper containing a screw feeder would feed a limestone slurry into the polluted water at a rate necessary to achieve neutralization.[14/] The water could then be gravity fed into a settling basin to remove the sludge.

For this simple treating facility, hereafter referred to as Method 1, capital costs involved would be pumps and hoses, flume, pipe and a hopper and mechanical screw feeder, plus construction cost of a settling basin or basins. Total capital costs would vary with the distances involved, but a reasonable assumption might be $2,000.00. Of this, $1,000.00 would be for motors, hose, pipe, screw machine, flume materials and assembly and an additional $1,000.00 for a settling basin of two or three acre feet capacity retained behind a semi-compacted earth dam with an overflow channel that would prevent erosion of the dam. Steeply sloping terrain would increase construction cost of the dam. Because of the movement of contour strippers along the hillside, it is assumed that at least three basins would be required over a ten year period.

[14/] Because the neutralization efficiency of limestone is low without aeration, it is assumed that two tons of limestone would be required to neutralize one ton of acid. The acidity of the water being treated is assumed to average 900 mg/l.

Operating costs would involve $30.00 per 8 hour shift in labor, $5.00 per ton of pulverized limestone, plus gasoline and oil and maintenance of the facility. The sludge would be left in the pond which would also serve to catch sediment during its useful life.

The total cost of treating water during an average year would be $2,333.00. The cost assumes that the company would treat water 50 times each year. The equipment would have a useful life of 10 years and three different sediment basins would have to be constructed during that period. Assuming that the company recovers 32,000 tons of coal on 10 acres of land that annually yield 5,430,000 gallons of run-off, the cost per ton for acid neutralization would be $0.073. The total annual costs are shown in Table 6.

TABLE 6

NEUTRALIZING FACILITY COSTS (METHOD 1)

Item	Annual Cost
Capital, plus 3 basins	$ 533.00
Labor, 50 days at $30.00 per day	1,500.00
Limestone, 40 tons	200.00
Fuel and Maintenance	100.00
TOTAL ANNUAL COST	$2,333.00

The primary drawback to this approach is that it probably would fail to handle portions of the water because of sheet wash that would go off immediately and the ponded water would percolate through the spoil and into the streams, or overflow during heavy rains. Standing water would have an opportunity to continuously react with the highly toxic material previously separated for burial.

An alternative technique available for preventing stream pollution from mine drainage is to utilize gravity flow and diversion around the pit. Hereafter this technique is referred to as Method 2.

The topography above the highwall is steeply sloping, yet somewhat undulating with natural drainage ditches that, before mining, carried run-off down the hill to the streams. By cutting diversion ditches along the contour above the highwall until the natural channel is intercepted water could be diverted around the pit, or across the pit at control points.

When the water has to be directed from above the highwall through the strip pit, a ditch should be cut in the pit to quickly and directly convey the water to a discharge point on the hillside below the spoil material from the first cut. Since spoil from successive cuts and the need to maintain haul roads would fill in the ditch, it would be necessary to use plastic or tile pipe to conduct the water from the open pit area to the discharge area. Extensions would be placed on the pipe with each new cut and the pipe beneath the spoil would be permanently buried.

In order to prevent accumulation of water in the pit, the underclay should be graded so that a slight slope in the direction of the ditch is created. In this way, the natural flow would carry all rain water immediately into a ditch and, through the pipe, over the hill.

Since the underclay and toxic material which had already been separated during the stripping process would contain pyritic matter which would form acid, the pit floor and toxic piles should be covered with pulverized limestone after each rainfall. The neutralizing agent could be applied with a regular farm lime spreader.

A highwall cut one mile long usually disturbs approximately 30 acres of land. That linear distance could reasonably be expected to have several points where natural drainage patterns would necessitate conducting water through the open pit. Therefore, it is doubtful that the discharge from any single point would be very large or sludge-laden. It appears unlikely that an operation the size of the target mine would generate enough acidic water under the above described conditions to necessitate settling basins for sludge removal at each discharge point.

The target mine estimates its cost of installing a diversion ditch to be $1.00 per linear foot, plus an upper limit of $100.00 per acre for scraping the under-clay and installing the ditch across the pit to utilize gravity discharge of rain water.[15] Plastic pipe cost would vary with the diameter and length. Assuming three inch diameter, the cost would be $0.60 per linear foot. Spreading of limestone in the pit would be between $10.00 and $15.00 per acre per application. U.S. Weather Bureau information indicates that it rains an average of 40 days per year in the study area.[16]

Assuming that one mile of highwall is created for every 30 acres of disturbed land in contour stripping, 10 acres of disturbed land would result in 1,760 linear feet of highwall. The total annual cost would be $7,060.00, and the cost per ton of coal for handling water using Method 2 would be $0.22. The costs are listed in Table 7.

15/ Includes cleaning an area 25 feet wide above the highwall. The ditch would be 3 feet deep with one to one grade on downside and two to one grade on up side. Hard rock would be hit at one foot depth.

16/ These are days in which measurable run-off would occur.

TABLE 7

WATER DIVERSION (METHOD 2)

Item	Cost
Highwall, 1,760 linear ft. at $1.00/ft.	$1,760.00
Scraping/acre at $100.00	1,000.00
Liming at $10.00 per acre 40 times each year.	4,000.00
Pipe 3 inch PVC at $0.60 per ft. and 50 ft. per acre.	300.00
TOTAL ANNUAL COST	$7,060.00

If a ponding arrangement were necessary, it should be one so constructed that it would handle sediment from erosion as well as sludge from the treated water. The cost of constructing a debris basin meeting the U.S. Soil Conservation Survey requirement and capable of handling 30 acre feet of water is estimated to be $4000.00. This cost assumes sloping terrain, but with a natural hollow, and some hard rock movement. Addition of the 30 acre foot pond would add $.031 per ton of coal. Combined with Method 2 to form Method 3, the cost per ton of coal would be $0.25.

Reclamation Costs

Reclamation costs include separating the toxic matter when removing the coal, grading the spoil to permit reforestation and reduce erosion, backfilling the final cut to a level six feet above the coal while burying the toxic material and planting seedlings in accordance with Ohio law.[17]

The target mine estimates its per month cost of separating toxic material when removing coal to be $400.00. Presently the company is mining slightly more than an acre per month. However, during the 1960's the average was less. Therefore, for purposes of quantification we will assume the $400.00 to be a per acre cost. The additional reclamation of grading, backfilling, burial of toxic materials, and reforestation is estimated to be $150.00 to $200.00 per acre.

The reclamation cost of $150.00 per acre would be $0.047 per ton if 3,200 tons per acre were mined (Technique 1). At $200.00 the reclamation cost under the same yield conditions would be $0.062 per ton of coal (Technique 2). To blast the highwall to a 45 degree angle and grade to the original contour and adequately seed with minimum erosion would cost about $500.00 per acre. At 3,200 tons of coal per acre the per ton cost would be $0.156 (Technique 3).

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[17] Reclamation definitions are variable and most do not include the separation of the toxic material during the process of removing the coal. However, it is an extra cost being incurred by miners since the passing of reclamation legislation. It should be noted that the target mine has been effectively complying with this requirement and has completely integrated it into the cost of mining coal.

CHAPTER IV

INDUSTRY AND TARGET MINE SUPPLY AND DEMAND RELATIONSHIPS

The Total Demand for Coal in the United States

The demand for coal is a derived demand. It is derived from the demand for electricity, for heat and for a multitude of other goods and services. This study does not estimate a total demand for coal as it is part of a complex demand for all types of energy and with substitution effects among coal, gas, oil, and atomic energy plus legislation on pollution limits, coal quality limits, etc., the model that would attempt to estimate the demand for coal would be quite extensive.[1/]

From recent experience regarding coal shortages, electricity blackouts, etc., it would seem that the demand for coal is expanding. Coal prices appear to be rising, particularly in the last two years, suggesting that even with expanded production of coal, the demand for coal is rising faster than production. It is likely that this situation will continue for some years until

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[1/] The Bituminous Coal Research, Inc. is currently developing such a model.

energy production facilities are expanded or the demand for energy subsides, the latter being least likely to happen.

While it is difficult to estimate precisely the total demand for coal, we can present total production figures for coal over the past ten years, and assuming that the market cleared in each year, we can assume that demand was equal to supply in those years, at least in the years when prices were reasonably stable which would be up to 1969. Production figures are presented in Table 8 for the United States, for Ohio and for southeast Ohio, the latter being the relevant market area of this study.

It can be seen from the table that the Ohio proportion of total U.S. output remained relatively constant over the decade. This was also true for the southeast Ohio proportion of Ohio's output except for several years.[2/]

Market Area of Target Mine

One of the advantages of studying an individual mine is the fact that a relatively identifiable and isolated market area can be defined. As has been mentioned earlier the target mine operates in several counties. This is true of several producers in Ohio,

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[2/] A detailed summary of production for these ten Ohio counties is contained in Appendix 2.

particularly the larger mines in northeastern Ohio. Map 1 on page 66 shows the market area for the firm encircled. The circle represents approximately a 50 mile radius from the mine.[3] This determination of the market was based upon several factors.

TABLE 8

TONS OF COAL PRODUCTION FOR THE UNITED STATES, OHIO AND S.E. OHIO, 1960-1969
(000 Omitted)

Year	United States	Ohio	Percent Of U.S. Total	S.E. Ohio	Percent Of Ohio Total
1960	415,512	33,896	8.0	7,651	22.5
1961	402,977	31,773	7.8	6,627	20.8
1962	422,149	34,125	8.1	6,971	20.2
1963	458,928	36,790	8.0	7,490	20.4
1964	486,998	37,310	7.7	8,402	22.5
1965	512,088	39,331	7.7	8,321	21.1
1966	533,881	43,068	8.1	7,360	17.2
1967	552,626	45,891	8.3	7,580	16.3
1968	545,245	48,286	8.8	9,966	20.5
1969	556,051	51,193	9.2	11,270	21.9

Source: National Coal Association, Bituminous Coal Data (Washington, D.C.: National Coal Association, 1969). Ohio data are from Department of Industrial Relations, State of Ohio, Division of Mines Annual Report (1960-1969).

[3] There are overlapping markets involved here. For instance, the target firm has shipped coal as far away as Dayton, Ohio. Moreover, the dominant firm in this market recently began trucking coal to Cincinnati, a distance of approximately 140 miles. In a period of rising prices, longer hauls will occur, although during the study period long trucked shipments were rare.

1. The target firm indicated a lack of capability of making a profit in hauling farther than 50 miles, which would be beyond Columbus, Ohio.

2. The firm does not ship by rail so trucking is its means of delivery on every contract. All of the producers in the Hocking-Perry county area ship almost exclusively by truck and are assumed to be subject to the same limitation as the target mine. The large firms in the area ship largely by rail and thus a market exists for truck sales and for rail sales and we have restricted the study to truck sales and to rail deliveries within the 50 mile radius. Table 9 indicates that most producers in the area ship exclusively by truck. It also shows the target mine's relative market share during the study period.

3. The 50 mile radius is applicable to the northwest and southwest from the mine since the market to the northeast and southeast is dominated by larger firms in Ohio, West Virginia and Kentucky, all of whom ship by rail, water, pipeline and truck and therefore do not truly represent competitors to the target mine.

4. By limiting the market to 50 miles and the truck sales we avoid the complication of Interstate Commerce Commission rate schedules which affect rail shipments primarily. As a matter of interest a favorable freight rate schedule can determine the market share for the larger firms, especially for long shipments in which frequently the shipping charges are greater than the cost of coal.[4]

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[4] Much of the information we have about the demand for coal from southeastern Ohio producers which we arbitrarily titled "the industry demand" has been derived from interviews and correspondence with executives of several of the largest coal producers in the country and from electric utility executives in Ohio cities. As one might imagine, most of this information is of a confidential nature and no references can be given. In fact, much of what we have concluded about the target mine's ability to control and pay for acid drainage programs, which inherently are based on the market model we derived is based on these interviews.

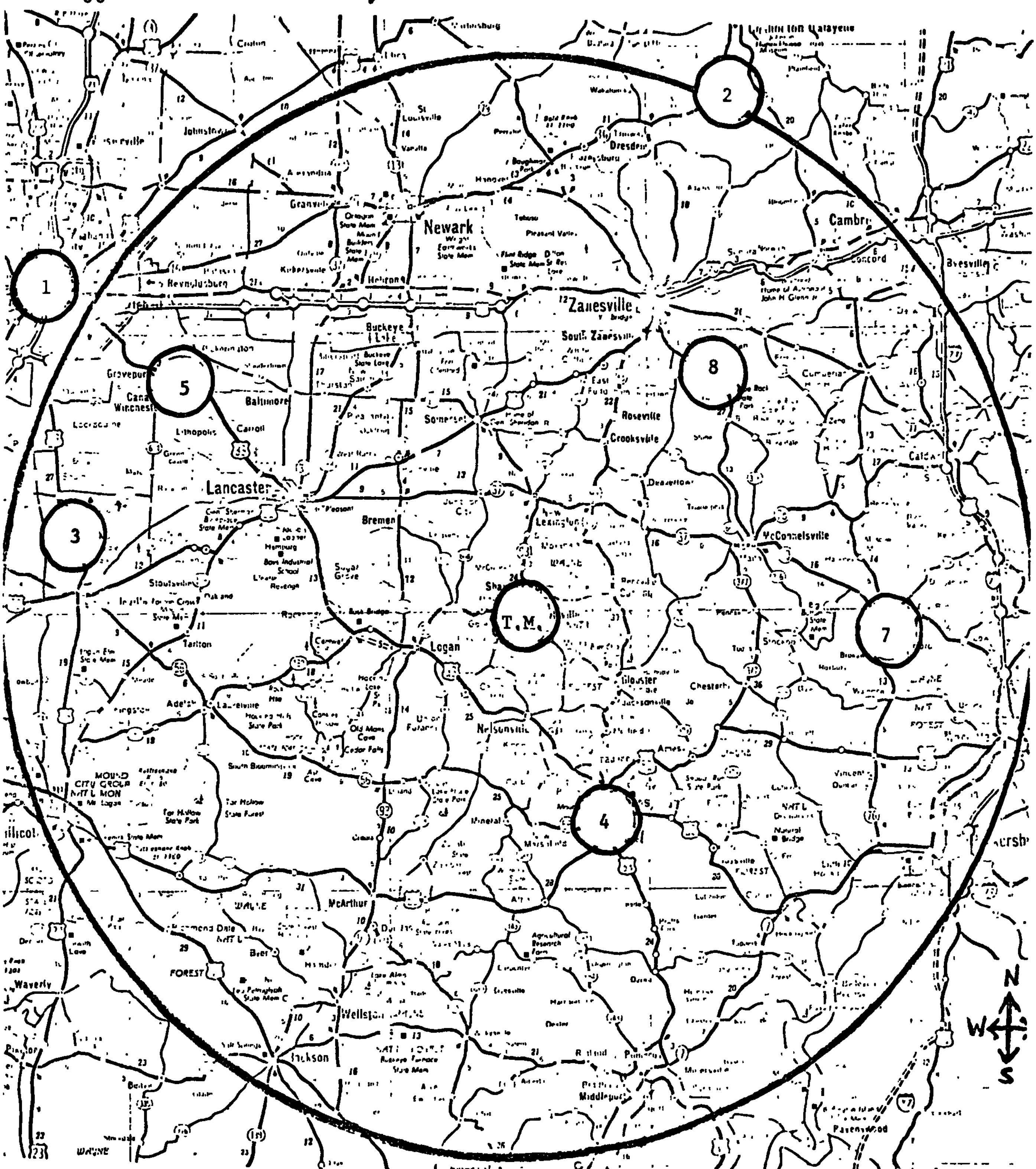
TABLE 9

RANKING OF TARGET MINE BY TONS PRODUCED, 1960-69 AND NUMBER SHIPPING BY TRUCK IN RELEVANT COUNTIES
(In Thousands Of Tons)

Year	County 1					County 2				
	Total Production	Number Producers	T.M. %	T.M. Rank	Shipped By Truck	Total Production	Number Producers	T.M. %	T.M. Rank	Shipped By Truck
1960	60,571	18	8.8	3	18	1,569.9	22	.8	9	19[a]
1961	54,919	13	0	0	13	1,684.4	19	1.0	6	15
1962	75,206	12	33.9	1	11	1,932.2	17	0	0	14
1963	81,965	7	35.3	1	7	2,031.7	17	0	0	15
1964	70,976	8	19.3	2	8	2,196.8	15	0	0	13
1965	104,084	9	32.1	1	8	2,092.4	15	0	0	13
1966	78,579	11	19.5	2	10	2,126.3	14	.4	8	12
1967	59,995	9	3.8	7	9	2,156.0	15	1.3	5	14
1968	129,834	9	16.2	2	9	3,101.5	14	.3	9	13
1969	95,406	8	18.1	2	8	3,303.7	13	.04	11	12

[a]The largest rail shipper consistently ships between 80-85% by rail.

T.M. = Target Mine



MAP 1

RELEVANT MARKET AREA OF TARGET MINE

The relevant market area for this study includes, therefore, the demand for coal from the ten coal producing counties of southeast Ohio by firms located within a 50-mile radius of the target mine. Counties excluded from this market include those along the Ohio River, which include the two largest coal producing counties in Ohio, Belmont and Harrison counties, and Guernsey County, the last being a very small producing county but nevertheless apparently involved in the eastern Ohio coal market.

There are several reasons for excluding Belmont and Harrison counties from our market area, the first being that we found little evidence that large coal buyers in our market purchased coal from producers in these counties except for industrial users along the Ohio River. Second, these counties appear to be in the very large and what appears to be very competitive market along the Ohio, West Virginia and Pennsylvania borders whose competitors ship by rail and water and service the steel and rubber industries of eastern Ohio and Pittsburgh. For instance, in 1969 of total production in Belmont county of 14,109,302 tons of coal, 11 million tons were shipped by rail and 2.5 million by water. In Harrison County, of 10.9 million tons produced, 10.2 million were shipped by rail and the rest by truck.[5]

There is some question by the largest mine owners whether the counties of Meigs and Washington should be included in their market areas since producers in these counties apparently service plants located on the river. However, they are not large producing counties and the coal is trucked from the producing mines. There is some evidence that firms in these counties do compete with the target mine for some accounts. However, all of the 1969 production is from one mine in both counties.

We have gone to some lengths to try to isolate the coal market in which the target firm operates. This is essential in order to understand the very nature of economic effects which we hope to determine. As with any market analysis there are arbitrary limits placed on the area but we feel that a reasonable series of assumptions help define the relevant market. It is, for instance, impossible to say very much about the demand for coal from our target mine without some delineation of the market and it is similarily impossible to discuss the industry demand (or what we call the demand for coal from southeastern Ohio producers) without some delineation of the market. To discuss elasticity

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[5] Ohio Department of Industrial Relations, Division of Mines Report (Ohio Department of Industrial Relations, 1969), p. 9.

of demand or shiftability of costs presumes a market area. Consequently, what we have done is absolutely critical to the rest of our study. Using the above delineation of the market area, we have concluded that the target mine is selling in what appears to be AN OLIGOPOLISTIC MARKET WITH PRICE LEADERSHIP BY A DOMINANT FIRM.[6/]

Broadening the scope of the market area would alter the market structure somewhat. However, in 1968 firms producing 50,000 tons of coal or less constituted 73 percent of all mines, although they produced only 10 percent of the coal.[7/] Therefore, a few large firms provide the vast majority of the coal at a price negotiated with electric utility companies who consume 61 percent of the coal produced in 1969. The large number of small companies then compete for the residual demand.

Besides the difficulty of defining a market area, there is an added difficulty in this study in defining the product. Coal is not a homogeneous product. The

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[6/] A description of such a market has been developed using traditional micro-theory and can be found in most intermediate economic theory texts. See Richard H. Leftwich, The Price System and Resource Allocation, 3rd ed. (New York: Holt, Rinehart and Winston, 1966), pp. 223-225.

[7/] Appendix 3.

quality of coal varies from one seam to another, as well as within a given seam. Examples of differences in coal are total sulphur content, organic sulphur content, pyritic sulphur content as well as the ash, moisture and heat content. These are some of the more obvious differences in coal and there are others of a more complex chemical nature. For any large user of coal, especially electric utilities, each shipment of coal must be tested for chemical characteristics and coal prices reflect these differences. In a given contract situation, other things being equal, the higher the BTU content of coal the higher the price. According to executives of several large coal producers, the rule of thumb is that the price of coal varies $.05 for each 100 increase in BTU content.

There are other characteristics which influence the coal market. For instance, many users of coal require that it be washed while others do not. The target mine does not wash its coal so it is excluded from selling to those customers who require washing.

Without further examples it should be apparent that not only is a given coal market constrained by overlapping market factors, the very product sold in a given market is subject to considerable variation. All of this tends to limit general statements and conclusions with respect to any specific behavior pattern discernible in a given competitive situation such as the one under study here.

Demand for Coal in the Market Area

Having outlined the relevant market area of the study and indicated the production from this market area, it is important to attempt to summarize the demand for coal in this market. As might be expected, coal use in southeast Ohio and coal use by firms buying coal from southeast Ohio resembles national patterns generally. This is shown in Table 10 which summarizes the major consumers of coal for 1966 and 1969.

Our estimate of the demand for coal from southeast Ohio producers theoretically comprises our INDUSTRY DEMAND CURVE. It should be apparent that several problems occur in attempting to determine an industry demand for coal on this basis. First, there are many coal users in southeast Ohio who do not report to state agencies, and whose coal usage data are impossible to acquire. These users, according to the target mine executives, include all the manufacturing and other types of firms that exist in southeast Ohio and quite naturally purchase coal from their closest suppliers, assuming quality is acceptable. Related to these users is the fact that many users of coal purchase from suppliers outside or on the periphery of our "market area."

TABLE 10

MAJOR CONSUMERS OF COAL, 1966 AND 1969
(In Thousands Of Tons)

	1966		1969			
	United States		United States		Ohio	
	Tons	%	Tons	%	Tons	%
Electric Power Utilities	264.2	54.3	308.4	60.8	32.7	52.6
Oven Coke	93.5	19.2	92.9	18.3	12.6	20.3
Other Manufacturing and Mining	89.3	18.4	78.6	15.5	----	-------
Retail Dealers	19.9	4.1	12.7	2.5	1.7	2.7
Cement Mills	9.1	1.9	9.1	1.8	----	-------
Steel and Rolling Mills	7.1	1.5	5.7	1.1	----	-------
Beehive Coke Plants	2.4	.5	-----	-----	----	-------
Bunker Foreign Trade	.6	.01	-----	-----	----	-------
Other	-----	------	-----	----	15.2	24.5
TOTAL	486.2	100.0	507.3	100.0	62.2	100.0
Exports	49.3		50.6			na
Total Production	533.8*		556.0			

*Totals are off apparently because of rounding.

Source: National Coal Association, Bituminous Coal Data (Washington, D.C.: National Coal Association, 1967 and 1969 editions).

For instance, all coal users in Columbus, or Dayton, Ohio could purchase coal from southeast Ohio producers, and in fact, probably do so, but these firms can purchase from other sources as well depending on shipping costs, quality requirements and related problems. This problem resembles the overlapping market problems mentioned previously. It is largely an insurmountable problem given the availability of coal use data now extant.

A second problem occurs in that there are many municipalities, villages, school districts in southeast Ohio which also use coal but for which data are not available. The State of Ohio keeps detailed records of coal used by Ohio institutions which purchase coal on term contracts through bid arrangements handled by the Department of Finance. There are a number of these institutions located in southeast Ohio which purchase coal from local producers, and have a large amount shipped into southeast Ohio. These include the Athens State Hospital, Orient State Hospital, Fairfield School for Boys and several others. Moreover, there are many state institutions located on the periphery of our market area and beyond which purchase coal from southeast Ohio producers. These include Ohio Penitentiary, Columbus State Hospital and others throughout the state. Other Ohio institutions throughout Ohio purchase coal from southeast Ohio producers and from other Ohio producers.

It should be mentioned that coal use has changed over the study period for many of these institutions due to sulphur content restrictions by cities or voluntary change to other energy sources. For instance, both Ohio State University and Ohio University have changed from coal to gas heating.

In terms of our specifications of the industry demand for coal, the public institutions represent a sizeable part of the market for which annual figures are available. Table 11 summarizes the major public institutions' demand for coal from southeast Ohio producers during the study period. Data are unavailable for several years and were approximated from previous years. The two years presented in Table 11 are typical of other years.

The total demand for coal by public institutions represents a part of our industry demand that is identifiable and for which the target mine could possibly compete. The other part of our industry demand is that attributable to other industrial users, retail and electric utilities. Electric utilities make up the largest part of coal demand nationally and for the state of Ohio. In recent years electric utilities absorbed 90 to 99 percent of the target mine's output. In Ohio the

TABLE 11

PUBLIC INSTITUTIONS' DEMAND FOR COAL, SELECTED YEARS

Public Institutions In Southeastern Ohio	1966			1969		
	Total Used (tons)	Trucked From S.E. Ohio*	Imported Into S.E. Ohio	Total Used	Trucked From S.E. Ohio	Imported Into S.E. Ohio
1) Athens State Hospital	11,000	11,000	0	0	0	0
2) Cambridge State Hospital	10,000	0	10,000	14,000	0	14,000
3) Columbus State Hospital	16,000	0	16,000	10,000	10,000	0
4) Columbus State School	8,000	8,000	0	10,000	10,000	0
5) Fairfield School for Boys	10,000	10,000	0	10,000	10,000	0
6) Juvenile Diagnostic Center	3,200	3,200	0	0	0	0
7) London Correctional Institute	12,000	0	12,000	15,000	0	15,000
8) Ohio Penitentiary	40,000	40,000	0	40,000	40,000	0
9) Ohio Penitentiary Maintenance	2,000	2,000	0	0	0	0
10) Ohio Reformatory for Women	3,600	0	3,600	3,000	0	3,000
11) Orient State Institution	20,000	20,000	0	20,000	20,000	0
12) Department of Public Works	3,000	0	3,000	0	0	0
13) Scioto Village	6,000	6,000	0	7,000	0	7,000

TABLE 11--CONTINUED

Public Institutions In Southeastern Ohio	1966			1969		
	Total Used (tons)	Trucked From S.E. Ohio*	Imported Into S.E. Ohio	Total Used	Trucked From S.E. Ohio	Imported Into S.E. Ohio
14) Southeast Ohio Mental Health Hospital	0	0	0	11,000	11,000	0
15) Southeast Ohio Tuberculosis Hospital	600	600	0	600	600	0
TOTALS	145,400	100,800	44,600	140,600	101,600	39,000
TOTAL DEMAND ALL PUBLIC INSTITUTIONS IN OHIO	355,000 tons			351,100 tons		

*Determination of amount trucked is based on contracts of previous years when method of shipment was indicated.

Source: State of Ohio, Department of Finance.

generation of electricity with coal as the energy source accounts for approximately 100 percent of the total electricity generated.[8]

Map 1 indicates the location of electricity generating plants that are served or could be served by southeast Ohio coal producers. These plants change over time in coal usage, generating capacity, quality of coal required and other ways. Table 12 summarizes the coal used by these plants in 1968 and 1969. Only the plants of Columbus and Southern Ohio Electric Company (hereafter referred to as C & SO Electric) numbered 2, 3, 4 and 5 and Columbus Division of Electricity represent the potential demand by electric utility generating plants from our target mine and its surrounding competitors.

As might be suspected the coal supply available to a generating plant has to be reasonably predictable over time. Given the large quantities of coal required for the typical generating plant and the certainty of delivery essential to this plant, it is understandable that long term contractual arrangements would exist between electric utilities and large coal producers. For instance, Eastern Associated Coal Corporation has contracted to deliver 2.0 million tons of coal in 1972

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[8] National Coal Association, Steam Electric Plant Factors (Washington, D.C.: National Coal Association, 1969).

TABLE 12

DEMAND FOR COAL BY ELECTRICITY GENERATING PLANTS
IN MARKET AREA OF TARGET MINE, 1968, 1969
(In Thousands Of Tons)

	Coal Demanded		Source	Method of Shipment*		Cost/Ton FOB Plant	
	1968	1969		1968	1969	1968	1969
1) Columbus Div. of Elec.	106.0	82.0	Ky.	N.A.	N.A.	7.24	7.57
Columbus and Southern Ohio Electric Company							
2) Conesville Plant	1197.0	1275.0	O.	TRK	TRK	4.29	4.54
3) Picway Plant	306.0	282.0	O.	RR	RR	6.82	7.25
4) Poston Plant	653.0	631.0	O.	TRK	TRK	4.73	4.99
5) Walnut Plant	93.0	93.0	O.	RR	RR	6.88	7.21
Ohio Power Company							
6) Cardinal Plant**	3154.0	2996.0	O.,W.Va.		RR,W	4.47	4.63
7) Muskingum Plant	2559.0	3630.0	O.		TRK,CON	3.85	4.19
8) Philo Plant	909.0	962.0	O.	TRK,RR	RR,TRK,UT	4.37	4.46
9) Tidd Plant**	522.0	569.0	O.	TRK	RR,TRK,UT	4.41	4.69

TABLE 12--CONTINUED

	Coal Demanded		Source	Method of Shipment*		Cost/Ton FOB Plant	
	1968	1969		1968	1969	1968	1969
10) Piqua Plant**	96.0	93.0	O.	RR	RR	N.A.	7.69
TOTAL	9595.0	10613.0					

*W = water transport; RR = railroad; CON = conveyor; UT = unit train; TRK = truck.

**These plants are actually outside our market area.

Source: National Coal Association, Steam Electric Plant Factors (Washington, D.C.: National Coal Association, 1969).

to the Detroit Edison Company and 3.5 million in subsequent years.[9] Referring to page 2 of Appendix 2, it can be seen that 2.0 million tons represents approximately 20 percent of southeast Ohio's 1969 production. Similarly, Eastern Associated Coal Corporation's 1968 production of 12.9 million was greater than southeast Ohio production for that year. Electric utilities in the market area served by our target firm use similar long term contractual arrangements for most of their coal purchases.

While Table 12 suggests that the electric utility companies represent a demand for coal slightly less than the total produced in southeast Ohio in 1968, several important factors about this demand must be noted. Coal for use by electric generating plants does constitute the largest part of the demand from southeast Ohio producers. According to a private survey by one mine in the market area, 74 percent of all coal produced in Ohio goes to electric utilities. It is estimated in the same report that 82 percent of the coal produced in the ten southeast Ohio counties goes to electric utilities. Of the ten producing counties in our market area, five ship 99 to 100 percent of their output to electric utilities based on 1967 data. It may be of interest to note that the same study points out that 50 percent of Ohio-produced

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[9] Dominion News, Morgantown, W.Va., Jan. 12, 1971, p. 13.

coal is exported out of the state and 70 percent of this goes to electric utilities.

Of the potential uses of coal in Table 12 which apparently amounts to 75 to 80 percent of the demand for coal from southeast Ohio producers, only four make up potential demand from the target mine. They are the Columbus Division of Electricity, and three plants of C & SO Electric, Picway, Poston and Walnut.

Ohio Power Company is controlled by American Power Systems and most of the coal used by Ohio Power Company plants is produced by captive mines, i.e., those owned by the utility itself. One of the largest of these captive mines in Ohio is Central Ohio Coal Company which is owned by Ohio Power Company. Although Central Ohio Coal, with its 1968 production of approximately 3.0 million tons of coal would not be able to supply all of Ohio Power's coal needs, it should be pointed out that the Cardinal and Tidd plants, both of which are located in Brilliant, Ohio, get their coal from West Virginia and Ohio. Being on the river and near West Virginia mines makes this reasonable and probably permits most of Central Ohio Coal's production to go to Ohio Power's other plants especially its Muskingum plant.

Subtracting Ohio Power usage from the total leaves a potential electric utility coal demand in 1969 of

2.5 million tons in Table 12. Almost half of this is absorbed by the Conesville Plant of C & SO Electric. This plant is located "on the coal" and according to confidential information is jointly owned by the utility company and a coal producer. The rest of the users listed in Table 12 theoretically represent potential customers for the target mine and its competitors. However, we have ruled out those outside the trucking market and this reduces the target mine's potential market even farther.[10/]

Further discussion of the relevant demand by electric utilities requires an explanation of how the demand for coal by utilities is satisfied and how our target mine competes for this demand. It must be remembered that C & SO Electric is, in essence, <u>the</u> demand for coal by electric utilities in southeast Ohio from the small southeast Ohio producers.

As with every utility C & SO Electric enters into long term contracts for coal. Usually, the utility contracts for up to 75 percent of its coal needs from one large producer and obtains the remainder from other producers, typically smaller producers within its area. The

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[10/] It should be noted that there may be other electric generating plants in the market area of our target mine but they are apparently so small that data are not published for them by the usual sources from which much of our information was obtained.

remainder of the market is distributed through coal brokers who have most of the small coal producers as clients.

Executives of our target mine stated that all of their small competitors sold exclusively through coal brokers, most of whom are located in Columbus, Ohio. Interviews with a large broker produced very little information about the operations of this type of business. The coal brokerage business is apparently a highly competitive market in itself. The typical arrangement calls for the client coal producers to be prepared to deliver given quantities of coal on a monthly basis with no chance for negotiation of price. The price quoted by the broker is always the delivered price and the producers must be able to mine and deliver at the broker's quoted price or forego the contract. The 20 or 30 year contract of the utility with its major producer contrasts sharply with the month to month arrangement of the small coal producers. As payment the broker usually receives $.20 to $.30 a ton commission and handles all paper work for the small producer.

Responsibility for delivering the proper quantity and quality of coal on time is up to the mine and failure to do so results in the loss of business. Over the last decade the target mine has delivered between 43 and 99 percent of its annual production to electric utilities. In those years when electric utility deliveries were down, the coal was trucked primarily to public institutions and a relatively small amount went to industrial users. The firm's retail business is very small as is true for most firms producing in southeast Ohio.

From the above description of how the electric utility demand is translated into coal sales for our target mine, it should be apparent that over the past 10 years our target mine and most of its small competitors have been dependent on the residual demand of C & SO Electric Company. While we do not know where each of the small competitors sold its coal, we know that many compete for the C & SO business. We do not know how individual brokers obtain their clients although this information is not really essential to our understanding of the target mine's behavior. The relationship with the broker may be explained by the fact that the target mine has no sales force and needs the broker more than the broker needs it. This situation may not prevail under different market conditions such as those now developing. During the study period it prevailed for our target mine and probably for most of its competitors.

Elasticity of Demand for Coal from Southeast Ohio Producers

While our market consists of utility demand, public institution demand, industrial demand and retail demand, it is difficult to specifically state the industry demand in southeast Ohio very accurately. It is known that electric utilities make up 75 percent, industrial users 20 percent and retail users 5 percent of the demand. Of the industrial users data are available for public institutions and this makes up only part of the demand.

Because it was impossible to obtain complete demand data for any period of the study, the options existed of trying to estimate the industry demand (i.e., the southeastern Ohio demand) from very limited data or of assuming a demand curve using available information, economic theory, and our general knowledge of the coal market. Both were attempted but the latter approach was adopted after considerable discussion with several econometricians and after several unsatisfactory attempts at statistical estimation. We simply have assumed an inelastic industry demand for coal for our study period.[11/]

[11/] A search of the literature produced no elasticity measure for coal. Furthermore, we have not documented non-economic factors that affect the elasticity of demand for coal such as ordinances requiring the burning of low sulphur coal, etc.

It is not unreasonable to assume an inelastic industry demand for coal in the short run since most coal using firms cannot switch to other energy sources readily and at lower cost. In fact, from looking at the figures in Table 13 it is apparent that coal costs would have to rise considerably before reaching the average BTU cost of other energy sources, even with other costs remaining constant. By the nature of the utility demand-coal supplier contractual arrangement, the industry demand appears to be inelastic since part of every contract requires renegotiation once a year to allow the coal producers to automatically pass forward any incremental costs that have occurred since the previous price was established.

With shipping costs an important determinant of coal sales, geographical limitations lend strength to our inelastic assumption. Moreover, large producers shipping by rail may have a significant freight rate advantage over distant potential suppliers. The dominant firm in our market area appears to have such an advantage. Thus, while C & SO Electric could contract with other large producers, it would need to go outside our market area to find sufficiently large producers. To do so would likely add considerably to its coal costs because of the additional shipping required.

TABLE 13

FUEL COSTS FOR ELECTRIC GENERATING PLANTS IN SELECTED OHIO CITIES, 1968

City	Company	Plant	Cost/Million BTU (Cents)				Per Cent Of Consumption In B.T.U.		
			F.O.B. Plant	As Burned					
			Coal	Coal	Oil	Gas	Coal	Oil	Gas
New Richmond	Cincinnati Gas & Electric Co.	W. C. Beckjord	21.9	22.5	70.9	-----	100	---	---
North Bend	Cincinnati Gas & Electric Co.	Miami Fort	20.3	21.5	83.2	-----	100	---	---
Cincinnati	Cincinnati Gas & Electric Co.	West End	22.9	24.4	-----	32.1	37	---	63
Ashtabula	Cleveland Elec. Illuminating Co.	Ashtabula	27.0 [8]	27.9 [8]	-----	-----	100	---	---
Avon Lake	Cleveland Elec. Illuminating Co.	Avon Lake	27.1 [8]	28.5 [8]	-----	-----	100	---	---
Eastlake	Cleveland Elec. Illuminating Co.	Eastlake	26.0 [8]	26.9 [8]	-----	-----	100	---	---
Cleveland	Cleveland Elec. Illuminating Co.	Lake Shore	26.6 [8]	27.5 [8]	-----	-----	100	---	---

TABLE 13--CONTINUED

City	Company	Plant	Cost/Million BTU (Cents)				Per Cent Of Consumption In B.T.U.		
			F.O.B. Plant	As Burned					
			Coal	Coal	Oil	Gas	Coal	Oil	Gas
Conesville	Columbus & Southern Ohio Elec. Co.	Conesville	19.1	19.4	77.5	----	100	---	---
Columbus	Columbus & Southern Ohio Elec. Co.	Picway	29.5	30.3	75.1	----	99	1	---
Athens	Columbus & Southern Ohio Elec. Co.	Poston	21.0	21.8	77.2	----	100	---	---
Columbus	Columbus & Southern Ohio Elec. Co.	Walnut	29.9	31.8	----	66.0	99	---	1
S. Dayton	Dayton Power & Light Company	O. H. Hutchings	28.6 [8]	28.9 [8]	----	----	100	---	---
Dayton	Dayton Power & Light Company	F. M. Tait	27.5 [8]	27.9 [8]	----	----	100	---	---
Miamisburg	Dayton Power & Light Company	Miamisburg [2] [29]	na	37.6	----	----	100	---	---

Source: National Coal Association, *Steam Electric Plant Factors* (Washington, D.C.: National Coal Association, 1968), pp. 13, 14.

It is likely that our industry demand curve is inelastic throughout the range relevant to our study period and under the conditions existing in the 1960's. Even the dominant firm feels that C & SO Electric could readily contract for coal from other Ohio producers, but this is less likely for other coal users since they are not large enough to affect price very much and using small quantities of coal suggests the likelihood of fewer discounts or economies than electric utilities probably now enjoy.

The important consequence of our assumption about an inelastic industry demand for coal is that coal buyers will be willing to pay higher prices for coal with very little substitution taking place in the short run. Moreover, it implies that coal suppliers would be able to pass forward to coal users almost all incremental costs of production regardless of their nature.

Target Mine's Demand Curve

From the industry demand for coal we move to the elasticity of demand for the target mine. In the past few years the target firm has supplied all of its output to the electric utility users. Its demand is thus a function of the residual demand of the electric utilities which is not provided by its long term supplier. From the firms we have talked with, this represents the best customer for the small producers under 1960-70 market conditions. Under these conditions the target firm has a perfectly elastic demand function since it must accept the broker's offered price and could likely do no better by selling on its own which would necessitate that it provide its own sales force. Finally, from our discussions with target mine officials and others, it was learned that the broker's price is not negotiable and remained quite stable over most of the study period.

There is in the southeast Ohio market a dominant producer just as there is in Ohio as suggested by the data in Appendix 5. So far as can be determined from our interviews, the dominant firm and electric utilities negotiate their long term contract and agree on an annual tonnage price, given the BTU content of coal and other quality characteristics that are agreed upon. The dominant producer provides up to 75 percent of the coal needs of the utility and the small coal producers supposedly provide the other 25 percent AT THE SAME PRICE AS THAT NEGOTIATED BY THE LARGE COAL SUPPLIER. This price is adjusted for the broker's commission since most of the residual suppliers sell through brokers. The broker distributes the business on a month-to-month basis to a number of firms.

The small firms in the market do not have to sell through brokers nor do they have to sell to electric utilities. For the stability and certainty it offers, most of these firms choose to operate in the above outlined market. In fact, with the brokers absorbing most of the sales, bookkeeping and other administrative costs, the electric utility may represent a relatively low cost-high profit market for many of the small producers.

In this market structure a small firm must know well its costs, particularly hauling costs, and its projected operating expenses in order to profit from the brokerage arrangement. This would be true under any contractual arrangements such as usually occur in the coal industry. Moreover, with some fixed costs from month to month such as debt services, depreciation and administrative costs, the firm may be better off by taking the broker's offer at a small loss than to discontinue operations in the short run.[12/]

[12/] We are convinced that the industry demand we are dealing with is derived from a more complex total energy demand and that our firm's demand function is clearly determined by the market structure in which it operates. We think that the industry demand could be reasonably approximated with considerably more data collection time and statistical experimentation. Moreover, we realize the serious limitations involved in representing a dynamic market situation with our very static approach to this market. For a more thorough discussion of these points see William J. Baumol, Economic Theory and Operations Analysis (Englewood Cliffs: Prentice Hall, Inc., 1965), 2nd ed., Chapter 10.

Target Mine's Supply Function

In order to estimate the target mine's ability to control its acid drainage and continue to operate profitably requires knowledge of its demand function and its supply function. In this section the supply function of the firm is estimated using accounting data provided by the firm. The supply function estimated is in fact the average cost function of the firm for four separate years. Where relevant to the adjustment process, marginal costs were also estimated.

The primary requirement in the decision to statistically estimate the average cost function was to obtain a series of data from the firm for periods in which all factors, except output, remained constant. This is very difficult to do for a strip mine since it typically strips at various locations moving equipment from place to place. Moreover, the overburden and seam thickness change even within a single cut around the hill. The amount of overburden and coal seam size are very important in the estimation of average cost, although there are many less important individual costs which, when aggregated, are considerable. However, the major variable cost in the stripping operation for the target mine is labor, with repair, gasoline and oil of secondary importance.

Table 14 presents total annual costs, revenues and average costs of the firm. Table 15 presents similar figures after deduction of non-coal income and expenses. Column 4 of Table 14 shows that the target mine suffered losses in four of the 11 years. Table 15 indicates losses per ton in six of the 11 years. Profits per ton of coal produced were greatest in 1961 under both calculations. However, some questions arise concerning which is the more appropriate measure of profit and loss for the company. Table 15 shows profits attributable to coal operations only. Average losses are much greater than average profits and losses occurred in five of the last seven years.

TABLE 14

UNADJUSTED TOTAL COSTS

Year	Total Cost	Total Revenue	Average Cost Per Ton	Profit Loss Per Ton Coal
1960	$ 87,089	$ 86,752	$4.86	-.019
1961	67,398	78,856	3.88	.660
1962	108,122	111,607	4.03	.130
1963	119,168	124,560	4.12	.186
1964	108,272	101,338	5.55	-.356
1965	149,552	152,549	4.47	.089
1966	142,589	149,037	6.26	.283
1967	147,600	157,123	4.86	.313
1968	155,565	154,604	4.86	-.030
1969	98,283	93,396	5.19	-.257
1970	245,421	267,028	5.69	.500

Source: Company records.

TABLE 15

ADJUSTED TOTAL COSTS

Year	Total Cost	Total Revenue	Average Cost Per Ton	Profit Loss Per Ton Coal
1960	$ 87,089	$ 84,992	$4.86	-.117
1961	67,019	77,517	3.86	.604
1962	108,602	111,157	4.03	.115
1963	119,088	123,424	4.11	.149
1964	106,343	95,908	5.45	-.535
1965	134,891	122,566	4.03	-.368
1966	120,303	101,891	5.28	-.808
1967	141,294	141,723	4.65	.014
1968	154,621	150,053	4.82	-.142
1969	98,283	93,396	5.19	-.257
1970	245,421	267,028	5.69	.500

Source: Company records.

Table 16 summarizes the per ton costs the firm experienced during the study period calculated from accounting data supplemented by verbal explanations from the mine owners. While there are no reclamation costs shown through 1968, the firm estimates that 35 acres have been reclaimed during the period at an approximate cost of $150 per acre. This cost is hidden in its labor and gasoline costs since reclamation primarily involves bulldozing and planting. Moreover, the firm estimates the cost of separating toxic material on top of the coal before loading to be about $.20 per ton, with an upper limit of $400 per month. If this were included in the reclamation

TABLE 16

TARGET MINE'S COST PER TON OF COAL MINED, 1960-1969*
(Unadjusted Costs Per Ton Of Coal Sold)

Year	Labor (1)	Royalty (2)	Hauling (3)	Oil & Gas (4)	Explosives (5)	Surveying (6)	Timber & Stripping Permits (7)
1960	$2.01	.240	.791	.429	.065	.004	.020
1961	1.92	.030	.254	.452	.045	.006	.027
1962	1.59	.058	.231	.338	.061	----	.015
1963	1.37	.135	.475	.316	.087	.003	.082
1964	2.11	.099	.648	.455	.144	.005	.006
1965	1.56	.083	.408	.364	.142	.005	.089
1966	2.00	.134	.829	.716	.110	----	.054
1967	1.61	.038	.834	.494	.198	.004	.049
1968	1.59	.105	.422	.450	.091	.004	.062
1969**	1.76	.060	.677	.643	.048	.003	.114
1970**	1.43	.116	1.410	.400	.060	.003	.050

Year	Electricity (8)	Depreciation (9)	Office Expenses (10)	Employees Welfare (11)	Taxes County (12)	Taxes Payroll (13)	Equipment Insurance (14)
1960	.005	.226	.031	.052	.016	.192	.047
1961	.009	.336	.014	.054	.016	.151	.048

TABLE 16--CONTINUED

Year	Electricity (8)	Depreciation (9)	Office Expenses (10)	Employees Welfare (11)	Taxes County (12)	Taxes Payroll (13)	Equipment Insurance (14)
1962	.016	.516	.077	.038	.018	.087	.052
1963	.027	.464	.061	.037	.045	.113	.045
1964	.035	.752	.024	.063	.070	.162	.069
1965	.026	.530	.041	.052	.064	.107	.051
1966	.029	.671	.114	.079	.040	.186	.084
1967	.025	.325	.100	.077	.325	.105	.085
1968	.024	.388	.064	.093	.183	.144	.090
1969	.030	.439	.044	.059	.121	.131	.103
1970	.030	.300	.033	.108	.124	.138	.120

Year	Depletion On Coal (15)	Buying Coal For Resale (16)	Reclamation Cost (17)	Cost Of Equip. Rep. Per Ton (18)	Ave. Delivered Sale Price Per Ton (19)	Average Cost Per Ton (20)
1960	----	----	----	.694	$4.59	$4.86
1961	----	----	----	.507	4.43	3.88
1962	.115	----	----	.734	4.33	4.03
1963	.168	----	----	.684	4.21	4.12
1964	----	----	----	.909	4.24	5.55

TABLE 16--CONTINUED

Year	Depletion On Coal (15)	Buying Coal For Resale (16)	Reclamation Cost (17)	Cost Of Equip. Rep. Per Ton (18)	Ave. Delivered Sale Price Per Ton (19)	Average Cost Per Ton (20)
1965	----	.067	----	.643	$4.45	$4.47
1966	----	----	----	1.160	4.47	6.26
1967	----	----	----	.657	4.50	4.86
1968	.012	.067	----	.886	4.52	4.86
1969	.115	.087	.015	.524	4.72	5.19
1970	.015	.040	.046	.867	6.19	5.69

*Coal and non-coal revenues and costs are included in these figures.

**1969 and 1970 figures across do not add to total in column 20 because of some overhead items not itemized in the table.

costs of the firm, these costs would be considerably higher. However, it seems reasonable to leave this latter cost in the stripping costs since the material is not in fact immediately returned to the pit and covered after the coal is removed. Consequently, this material adds to the firm's water acidity problems and can hardly be considered a positive cost of reclamation or acid control. This is typical of the difficult decision needed to isolate costs and activities in this kind of operation.

Because of difficulties involved in using annual cost and production data, it was decided that monthly figures would provide the best possible source of information for an average cost function. The target mine officials were asked to supply monthly costs for whatever specific operations data were kept. The figures provided were monthly labor, repair, and hauling costs. The firm was asked, furthermore, to provide these data for periods in which the firm was operating in the same relative area of overburden, rock content of overburden and coal seam width. Several such periods existed and these data were used in estimating the average cost functions. No attempt was made to analyze data from an operation in a particular environment that was of less than one year.

Charts 1, 2, 3 and 4 present average costs based on monthly labor, repair, and hauling costs and an approximation of all other costs. Total annual labor, repair and hauling costs were subtracted from total annual costs, which leaves total annual costs attributable to all other factors. This residual figure was divided by 12, resulting in a monthly estimate for all other costs. Adding this constant to actual monthly labor, repairs, and hauling costs gave a total monthly cost figure which, when divided by monthly production figures, provided an average cost figure for each month. The years 1965, 1966, 1969 and 1970 are those in which production costs and technology were reasonably constant. This approach gives theoretically appealing downward sloping cost functions. The estimating equations fitted to the data are summarized in Table 17.

For each year the equations written on the Charts represent a least squares fit to the data and in each: X_1 = tons produced each month; $X_2 = X_1^2$; u is the residual. By introducing X_2 into the equations, we essentially obtain a curvilinear fit to the data. This was done to see if the average cost curve slope would become positive at some level of output rather than have a continuous negative slope, i.e., a declining marginal cost.

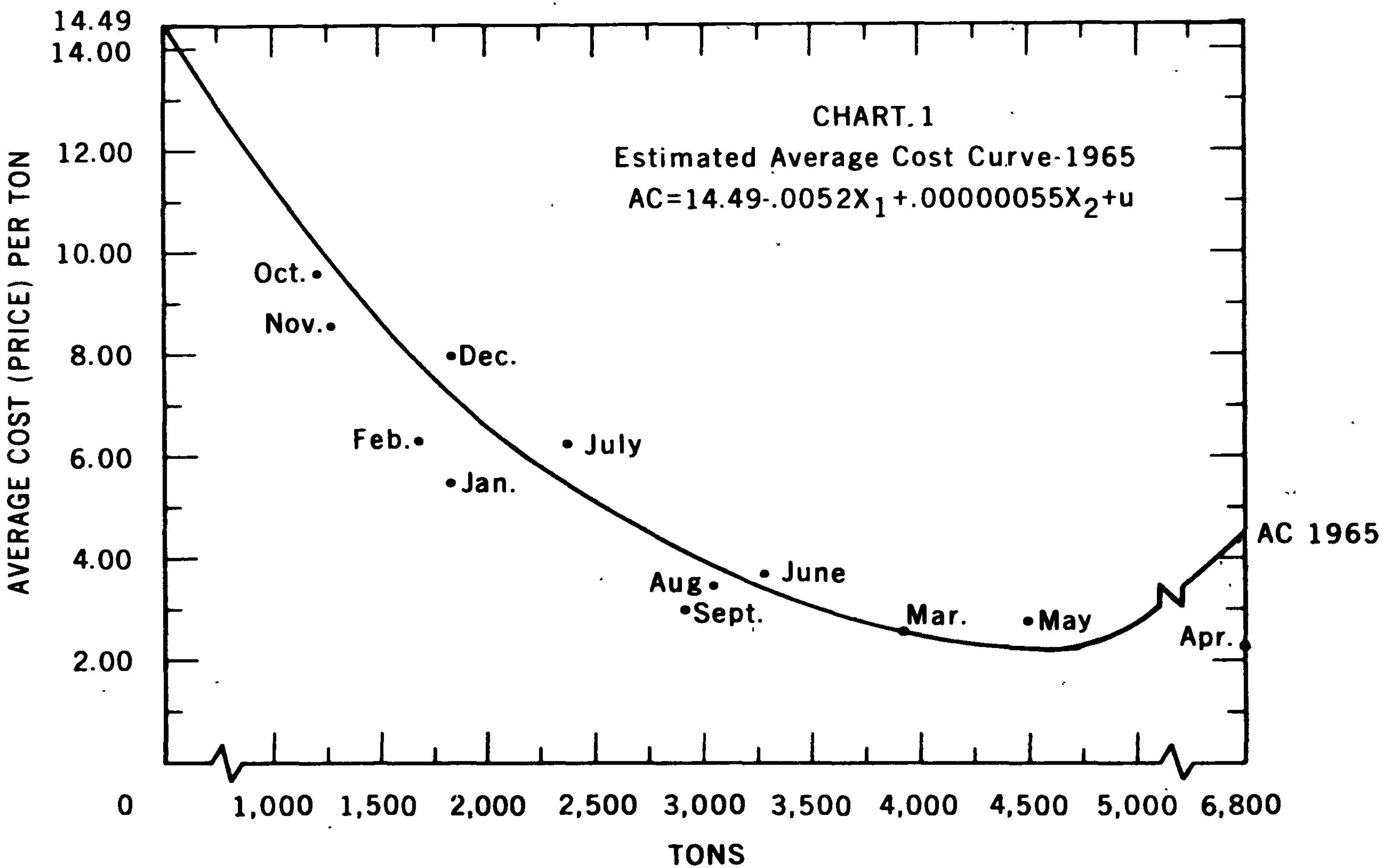
CHART. 1
Estimated Average Cost Curve-1965
AC=14.49-.0052X1+.00000055X2+u
AVERAGE COST (PRICE) PER TON
14.49
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
6,800
TONS
Oct.
Nov.
Dec.
Feb.
Jan.
July
Aug
Sept.
June
Mar.
May
Apr.
AC 1965

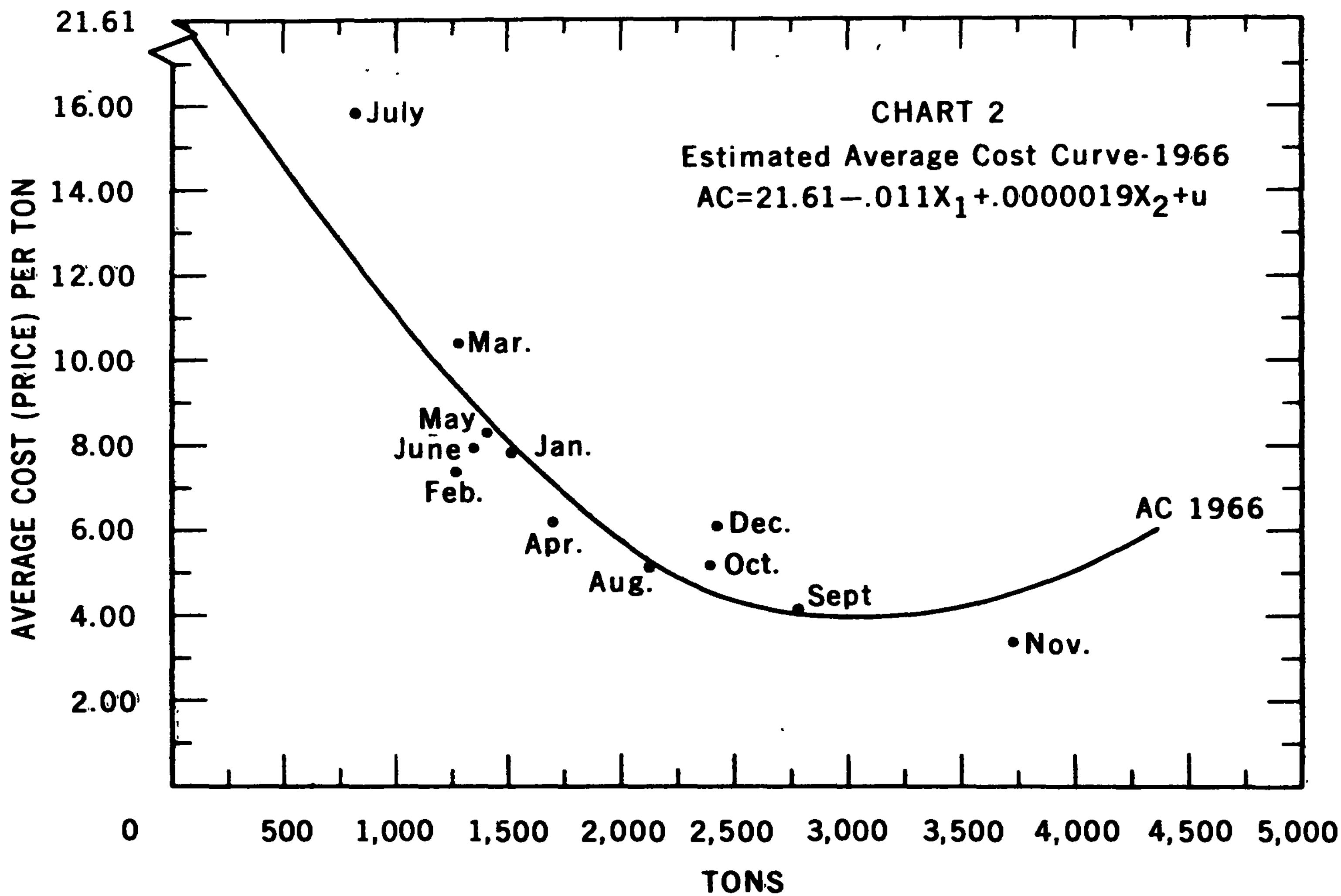

CHART 2
Estimated Average Cost Curve-1966
$AC=21.61-.011X_1+.0000019X_2+u$

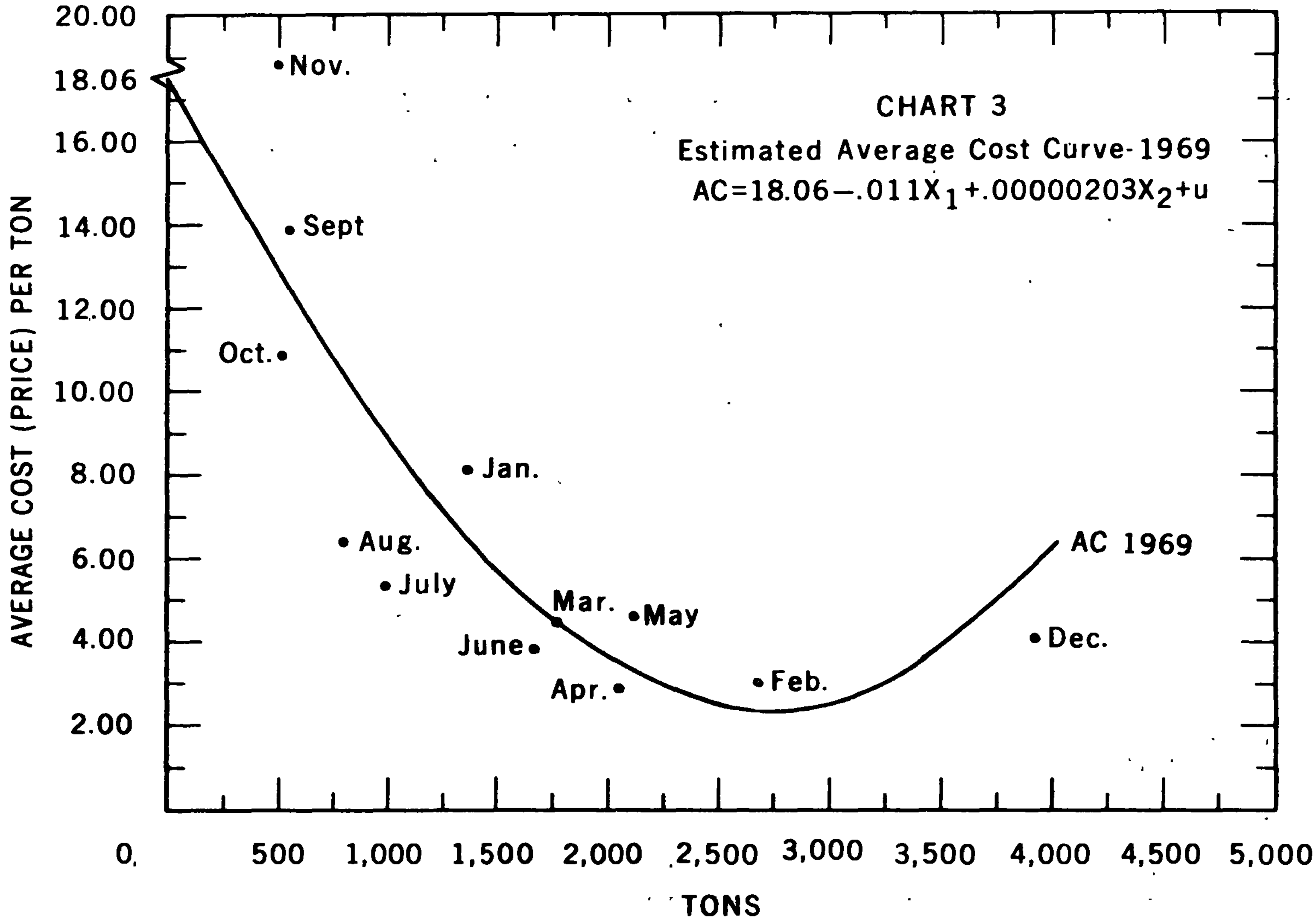
CHART 3
Estimated Average Cost Curve-1969
AC=18.06−.011X1+.00000203X2+u
AC 1969
AVERAGE COST (PRICE) PER TON
TONS
20.00
18.06
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Nov.
Sept
Oct.
Jan.
Aug.
July
Mar.
May
June
Apr.
Feb.
Dec.

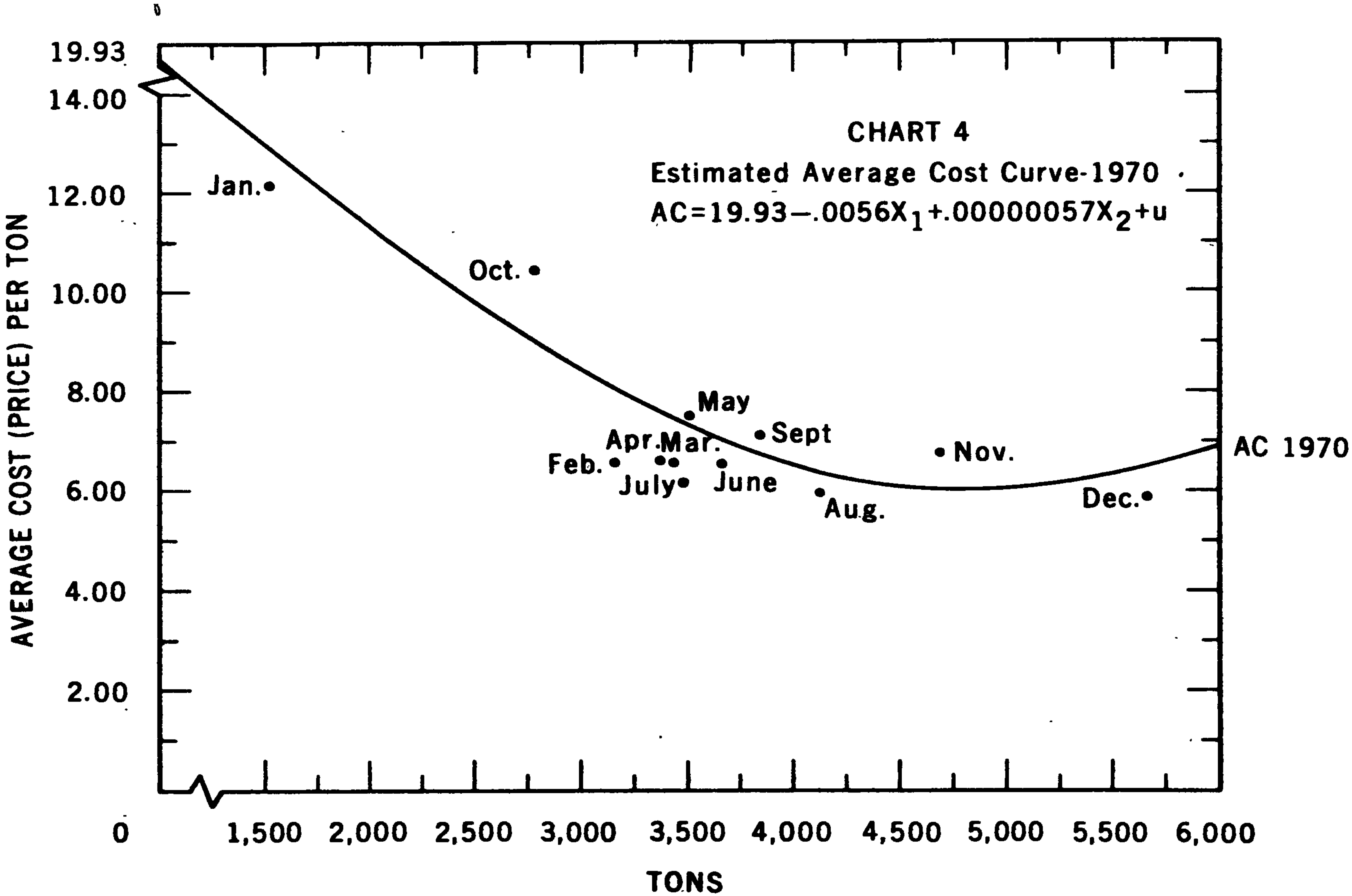

CHART 4

Estimated Average Cost Curve-1970

$AC = 19.93 - .0056X_1 + .00000057X_2 + u$

TABLE 17

ESTIMATING EQUATIONS FOR AVERAGE COST FUNCTIONS

AC_{1965}	= 14.49	−	$0.00520X_1$	+	$0.00000055X_2$	+	u
	(1.41)		(.00099)		(.00000015)		
	10.20		5.209		3.60		
AC_{1966}	= 21.61	−	$.01176X_1$	+	$.00000190X_2$	+	u
	(2.90)		(.0028)		(.00000062)		
	7.45		4.128		3.042		
AC_{1969}	= 18.06	−	$.01137X_1$	+	$.00000203X_2$	+	u
	(2.45)		(.0028)		(.00000067)		
	7.35		4.008		3.00		
AC_{1970}	= 19.93	−	$.00566X_1$	+	$.00000057X_2$	+	u
	(2.43)		(.0013)		(.00000018)		
	8.17		4.28		3.234		

Note: Standard errors are in parentheses under the estimated coefficients and *t* ratios are under the standard errors. A .05 percent significance level was used for each equation.

In each equation X_2 is statistically significant at a .05 percent significance level (see the t ratios). This suggests that as output continued increasing under the cost conditions used in the equations average cost would become positive, and that marginal cost would rise above average cost giving what could be thought of as a typical theoretical supply curve. Using only X_1 in the equations would require that we present our cost curves with constant slopes. However, with the results using X_2 we can draw a curvilinear cost curve as illustrated in all of the charts. The output levels at which the slope of the average cost becomes positive for each year have been calculated and are presented in Table 18. For instance, this would occur at an output of approximately 4,971 tons a month in Chart 4. Table 18 also shows the average monthly and profit maximizing output levels of the target mine.

TABLE 18

ACTUAL, MINIMUM COST AND MAXIMUM PROFIT
OUTPUT LEVELS OF TARGET MINE
(Tons)

Year	Actual Average Monthly Output (1)	Minimum Cost Monthly Output (2)	Maximum Profit Monthly Output (MC = AR) (3)
1965	2,788	4,728	5,113
1966	1,898	3,094	3,179
1969	1,579	2,800	3,005
1970	3,620	4,971	5,031

We believe this is an acceptable statistical method. It should be pointed out that in every instance on the basis of our calculations the firm can have added output at lower average cost of production in the short run. The critical question is when will its costs begin to rise and what external factors might influence these costs, e.g., the need for expansion or possibly unionization of its employees. This question is discussed in Chapter V.

Several interesting problems are highlighted by the Charts. In 1965, which is one of the most typical experiences of the firm (if a typical year can in fact be identified), the months of November, December, January and February are at the low output high cost part of the curve. In 1970, the months of November and December appear at the other end of the curve. The firm estimates that five working days a month are missed on average during January through April due to bad weather conditions, while three days a month are lost on average in other months. During winter months efficiency declines even on working days because of the condition of pits and roads. The 1970 exception to this pattern is easily explained by the fact that the firm fortuitously happened upon a four foot seam of No. 7 coal very close to the top of a hill being stripped. The stripping was being done to uncover No. 6a coal several yards underground. This extremely unusual windfall resulted in the firm's largest monthly output ever produced at relatively low average cost.

The 1970 curve lies above the other years because all cost began rising for the firm in late 1969 and continued rising during 1970. By the firm's account, all costs were relatively stable until 1969, including its hourly labor cost. The only exception was repair costs which the firm estimates doubled during the decade. These cost increases explain the position of the various average cost curves but have little to do in explaining their shapes.

The appropriate way to estimate the average cost function using monthly data would be to have monthly costs for all activities of the mine. Unfortunately, these are not available although the firm provided all of the monthly cost items it could, trying particularly to get accurate labor, repair and hauling costs. Of the four years for which monthly data were provided, we have taken the 1965 and 1966 experiences to be most typical for the firm although the firm experienced relatively low repair costs in 1965. In 1969 the firm became involved in non-mining activity and in 1970 unusual cost increases took place, a No. 7 seam was fortuitously discovered, and the market price of coal was rising quite rapidly.

In the next chapter the economic effects of alternative water quality programs will be presented using the cost curves estimated from the monthly data.

CHAPTER V

IMPACT OF MINE DRAINAGE ABATEMENT AND RECLAMATION ON TARGET MINE

As discussed in Chapter II, the Ohio water quality legislation had no impact upon the target mine in the 1960's. The long history of mining in the region had so degraded the water quality that the State legally permitted miners to discharge their effluent into the streams without treatment so long as further degradation did not occur. Therefore, any water costs incurred by the mine were associated with removing water interferring with active mining.

The target mine had some reclamation expenses during the sixties, although the amounts are difficult to ascertain because separate records were not kept for reclamation activity. The company separates its toxic materials for future burial and, during the 1960's, reclaimed 35 acres in compliance with State and Federal regulations.

The State has been willing to allow firms to postpone reclamation if the company plans to return to the area for further stripping. The target mine deferred much of its reclamation of disturbed land because of its intent to take additional cuts after acquiring larger equipment.[1]

The records of the target mine list only annual reclamation costs associated with the purchase of trees acquired for planting on reclaimed land. Company officials estimate that the total cost of grading, backfilling, and reforestation was $150.00 per acre for the 35 reclaimed acres.

Short Run Output Adjustment

While it is difficult to clearly isolate water treatment costs from general reclamation costs in an ongoing mining operation, it is attempted in this section to illustrate the firm's adjustments to these costs and the market effects these additional costs would have. In Chapter III the costs of various water management and reclamation techniques which the target mine could adopt were presented and discussed. In this chapter the four alternative acid control programs and two of the reclamation techniques outlined in Chapter III will be illustrated with respect to the effect each might have on the firm's output. The alternative methods are illustrated

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[1] The attitude of the State officials towards deferring reclamation has been altered and the target mine must reclaim most of the previously disturbed acreage during the first half of 1971.

in Charts 5, 6, 7 and 8 by shifting the firm's average cost functions for the four years 1965, 1966, 1969 and 1970. In each chart the firm's demand curve is illustrated as perfectly elastic. The explanations for this important conclusion were presented in Chapter IV. Finally, the analysis is basically short-run because it is assumed that some costs remain fixed during the adjustment process. Some implications for long-run adjustment are discussed later.

Method 1 would add approximately \$.073 to the firm's average cost of production. Methods 2 and 3 combined would add \$.250 per ton to its average cost and method 4 would add approximately \$.090 per ton to its average cost. It should be recalled that the target mine had average losses per ton in five of the last seven years of its operation. To avoid larger losses per ton the firm could expand output to absorb the higher cost of the water control program. With declining average costs the firm apparently would have had little difficulty absorbing the higher cost in 1965 and 1969, even for the most expensive treatment method. The firm could absorb additional water control costs by increasing output and moving down its average cost curve to a lower average cost output level or where its rising marginal cost (MC) = average revenue or price per ton (AR). This output level is presented for the

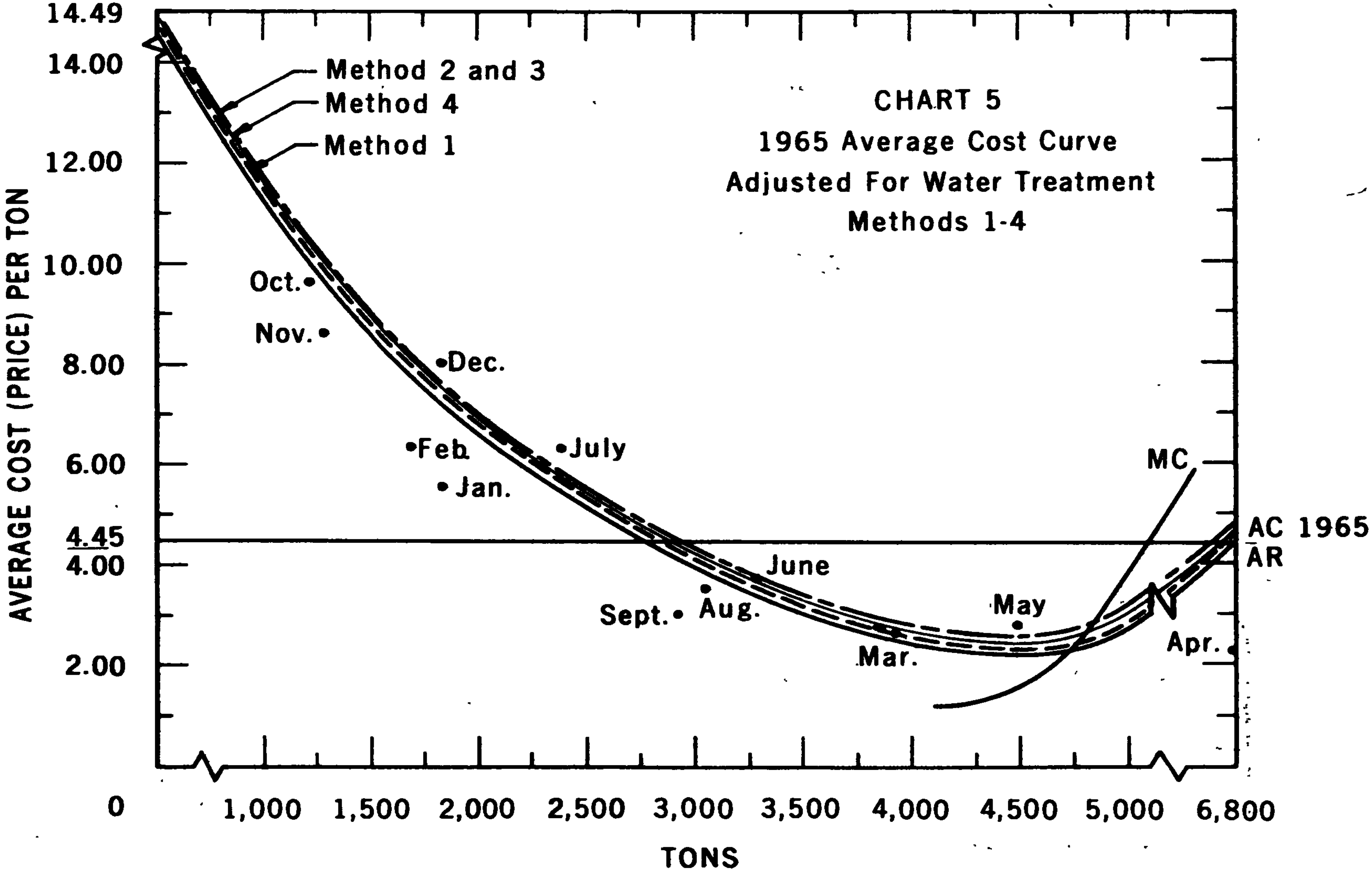
CHART 5
1965 Average Cost Curve
Adjusted For Water Treatment
Methods 1-4
Method 2 and 3
Method 4
Method 1
AVERAGE COST (PRICE) PER TON
14.49
14.00
12.00
10.00
8.00
6.00
4.45
4.00
2.00
0
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
6,800
TONS
Oct.
Nov.
Dec.
Feb.
Jan.
July
June
Sept.
Aug.
Mar.
May
Apr.
MC
AC 1965
AR

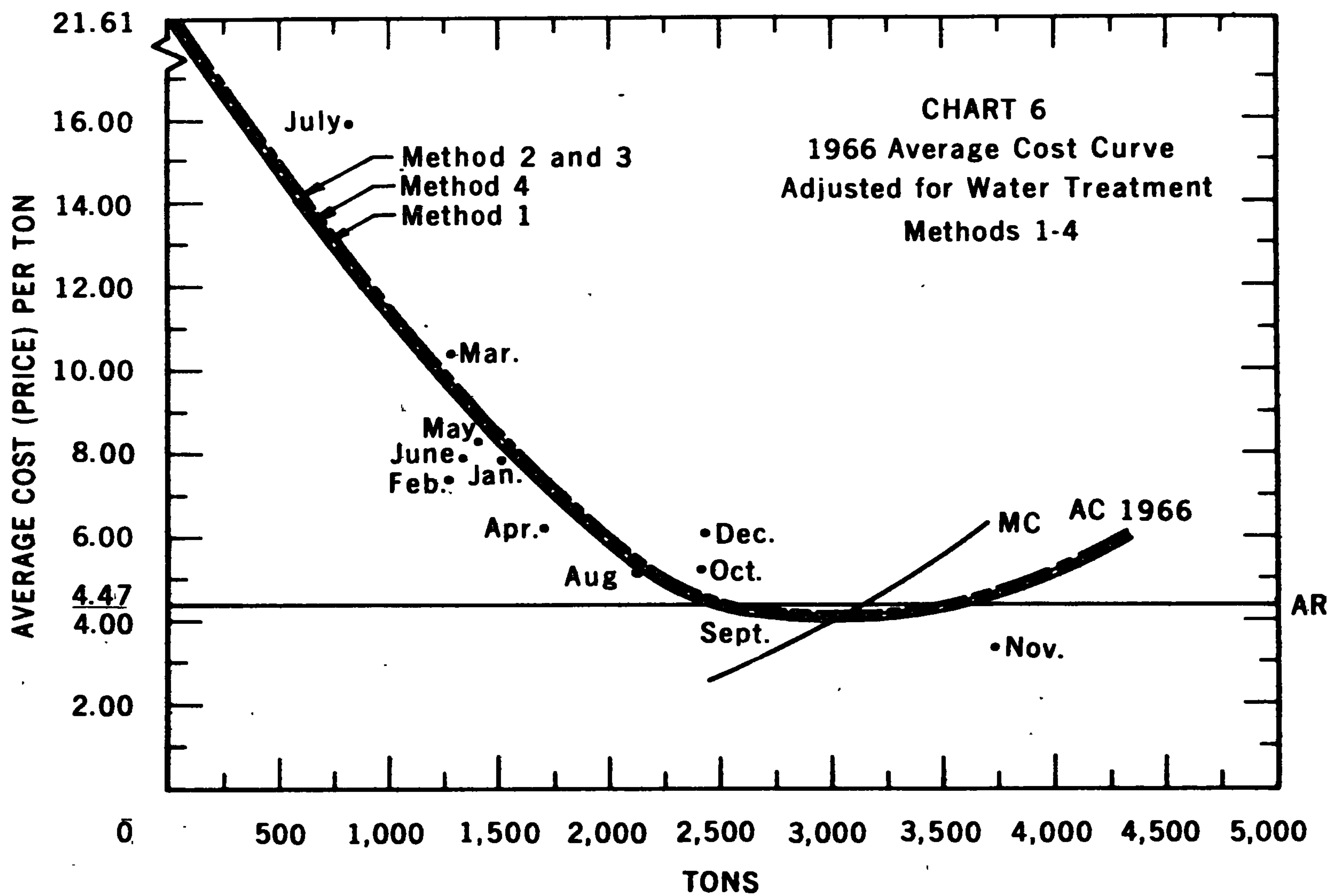

CHART 6
1966 Average Cost Curve
Adjusted for Water Treatment
Methods 1-4
AVERAGE COST (PRICE) PER TON
21.61
16.00
14.00
12.00
10.00
8.00
6.00
4.47
4.00
2.00
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
TONS
Method 2 and 3
Method 4
Method 1
July
Mar.
May
June
Feb.
Jan.
Apr.
Aug
Dec.
Oct.
Sept.
Nov.
MC
AC 1966
AR

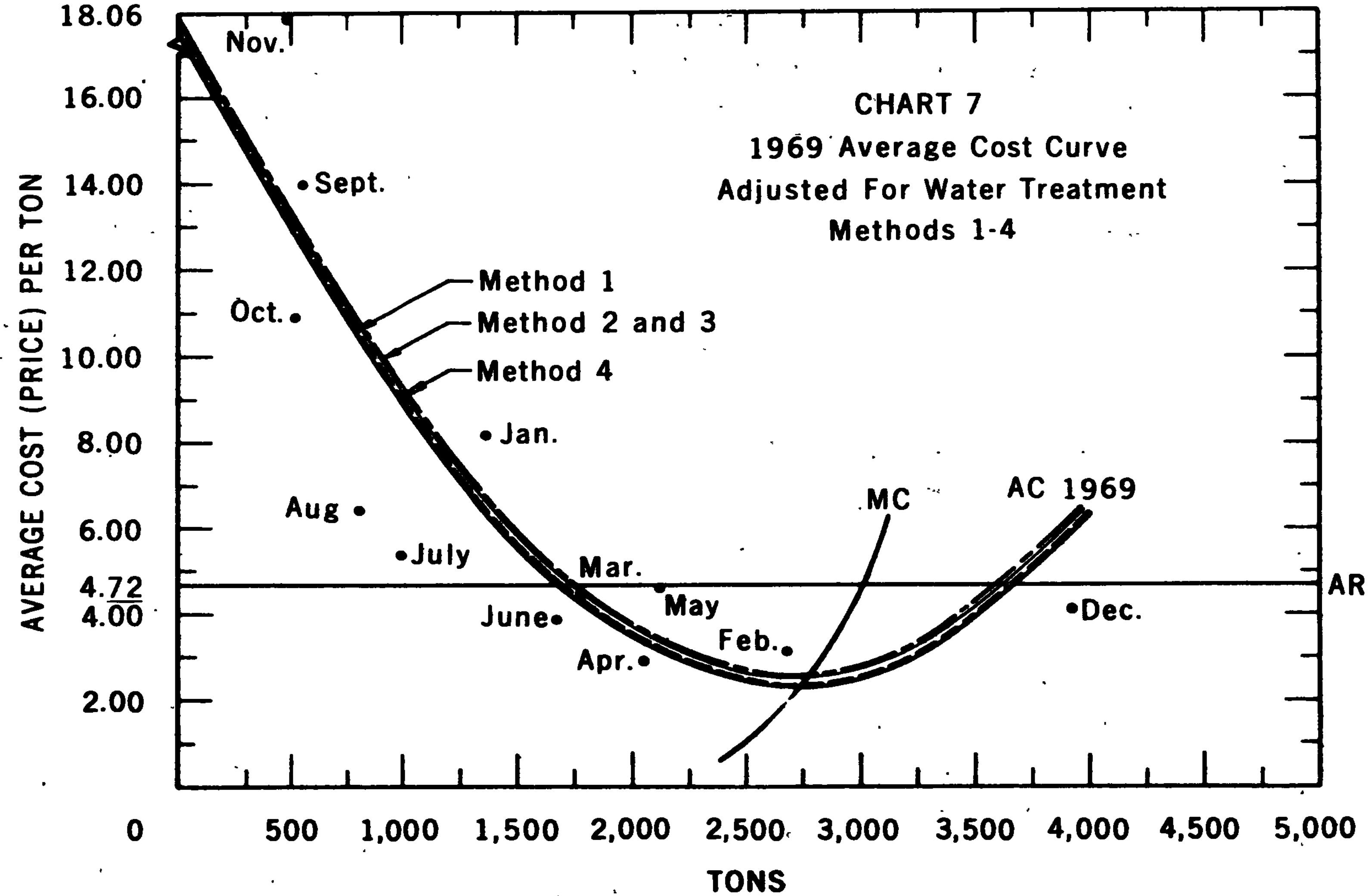
CHART 7
1969 Average Cost Curve
Adjusted For Water Treatment
Methods 1-4
Method 1
Method 2 and 3
Method 4
AVERAGE COST (PRICE) PER TON
18.06
16.00
14.00
12.00
10.00
8.00
6.00
4.72
4.00
2.00
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
TONS
Nov.
Sept.
Oct.
Jan.
Aug
July
Mar.
May
June
Apr.
Feb.
Dec.
MC
AC 1969
AR

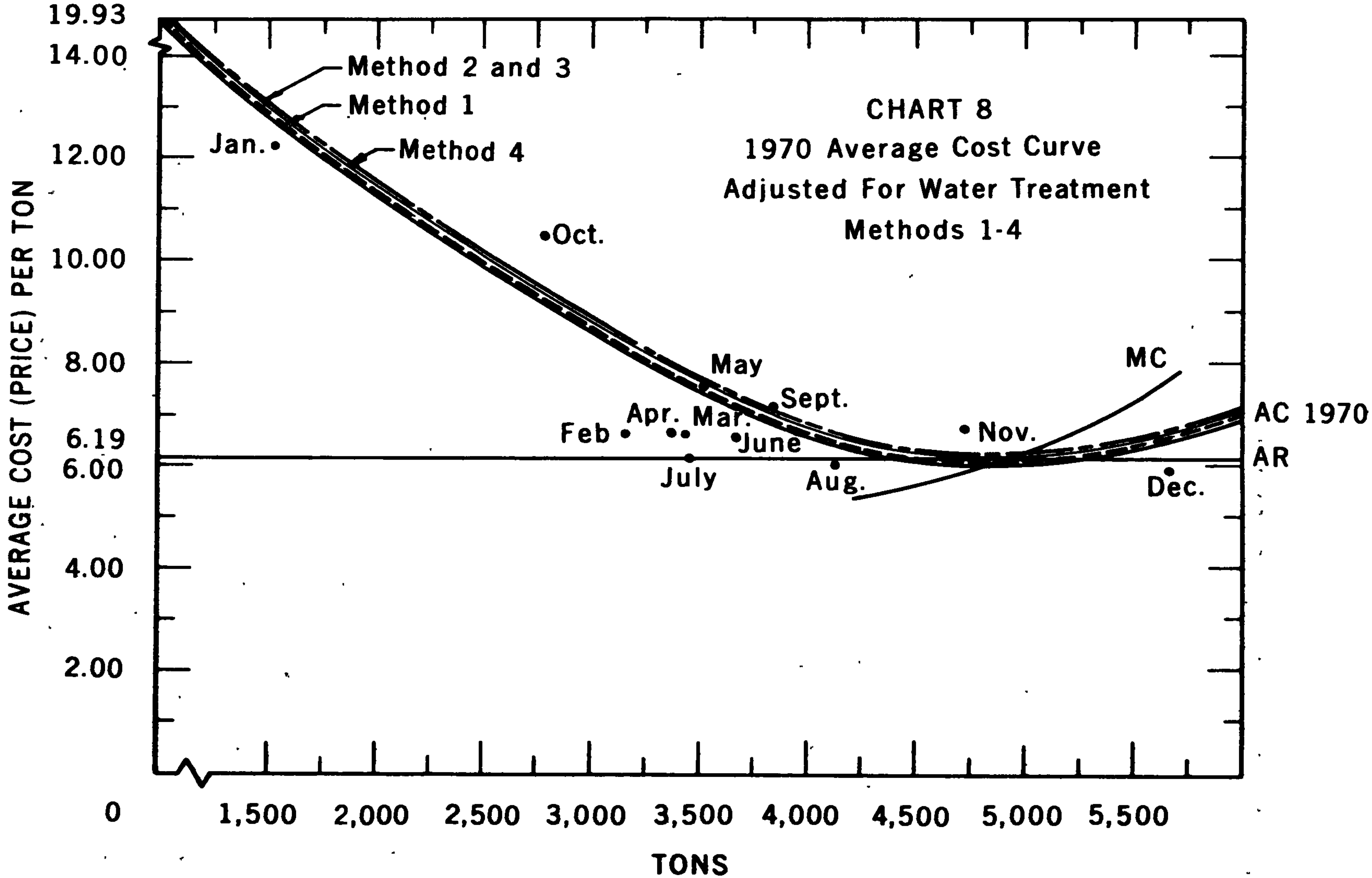

CHART 8
1970 Average Cost Curve
Adjusted For Water Treatment
Methods 1-4
Method 2 and 3
Method 1
Method 4
Jan.
Oct.
May
Sept.
Apr.
Mar.
Feb
June
July
Aug.
Nov.
Dec.
MC
AC 1970
AR
AVERAGE COST (PRICE) PER TON
19.93
14.00
12.00
10.00
8.00
6.19
6.00
4.00
2.00
0
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
5,500
TONS

four years in Column 3 of Table 18. In 1966, the firm could have increased output to a lesser degree to absorb the acid control costs of methods 1, 2, 3 and 4. In 1970, it could have sbsorbed only the additional cost of methods 1 and 4.

The average cost functions estimated from our equations suggest a declining average cost up to some average monthly output which the firm seldom achieved beyond which point it became positively sloped. This output level is presented in Column 2 of Table 18. In none of the years was the firm's average monthly output near the minimum cost output level nor the approximate profit maximization output level where MC = AR.[2/] In 1970, the firm approached its most profitable output level more closely than in any other year, i.e., its actual average monthly output level was 72 percent of the MC = AR level. Again, this

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[2/]While the proper solution would involve the equality of MC = AR, the firm never achieved its lowest average cost output level so any increase in its average monthly output would have improved its profit position. It may thus be somewhat spurious for us to dwell on an MC = AR solution. This is especially true in those years in which its estimated minimum cost output is quite close to its AR, i.e., in 1966 and 1970.

We have ignored the possibility of the firm negotiating a higher market price for its coal, an obvious solution for offsetting the higher costs if it were possible. However, as indicated in Chapter IV, this is impossible for the firm under the existing market structure in which it sells, and therefore, it is likely that the firm must absorb all additional costs itself unless the market price is forced up by pressure from the dominant firm in the industry.

is ignoring the rate at which its costs were changing. We believe and have some information to suspect that the firm's average cost in the short run begins rising rapidly even before the lowest cost levels shown in the charts. The functions shown may thus not represent the most likely range of adjustment for the firm in the short-run.

The firm estimates that it can produce about 4500-4800 tons per month under present conditions. These capacity conditions existed during several periods of the study but existed consistently in several months of 1970. They include a six-day work week, with time and one-half for employees for all hours over 40 per week. The work day is generally from dawn to dusk and equipment maintenance is quite poor under these circumstances and, in fact, repairs begin to increase during these maximum output periods. Thus, while the plotted functions suggest considerable flexibility in expanding output to absorb higher costs especially under 1965 and 1969 conditions, it is our conclusion that the range within which this expansion could reasonably occur is quite limited in the short run probably resembling the 1966 and 1970 conditions.

If worker productivity and other factors were introduced into the equations, the average cost curves would very likely have different shapes and become steeply sloped below what the firm considers its most efficient capacity level. For instance, this would likely occur at an output below what the firm considers its most efficient capacity level of 4500-4800 tons per month in 1970.[3/] The data in Table 19 show that the target mine's productivity is considerably below the Ohio or United States average. We suspect that a similar productivity pattern exists for most of its small competitors as well. Moreover, we suspect that the target mine's productivity begins to decline even before it attains what the executives call the maximum capacity output level. Consequently, the firm might be able to expand sufficiently to absorb the cost associated with acid control Method 1, the additional $.07 per ton, but if one recalls that the firm had losses in most of the 1960's, and that its only recent profit except for 1970 was $.01 a ton in 1967, then an additional $.07 cost is quite meaningful to the firm. To absorb the costs of Methods 2 and 3 would be most unlikely for the firm, assuming its costs rise sharply beyond the 4500-4800 tons of output per month. Were the firm enjoying profits each year the additional cost of acid control would be easier

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[3/] If the firm's productivity improved, it would result in a shift downward in the average cost function, making the firm's adjustment easier. This would represent a long-run adjustment by usual definitions of long and short run cost behavior.

TABLE 19

OUTPUT PER MAN DAY, TARGET MINE, OHIO, U.S., 1960-1969

Year	Target Mine Output Per Man Day (Tons)	Ohio Average Output Per Man Day (Tons)* (Stripped)	U.S. Average Output Per Man Day (Tons)* (Stripped)
1960	12.2	23.59	22.93
1961	16.8	24.28	25.00
1962	19.2	24.03	26.76
1963	19.8	25.91	28.69
1964	19.2	21.12	29.29
1965	17.1	29.33	31.98
1966	14.8	30.36	33.57
1967	15.17	33.51	33.17
1968	19.06		
1969	18.9		
Simple average	17.2 (10 years)		

*Source: National Coal Association, Bituminous Coal Data, 1964, 1967 and 1969.

to absorb, particularly if its average cost functions resembled those for 1965.

Long-Run Adjustments

There is another alternative adjustment that the firm could make. This would involve a change in its scale of operations. The firm could increase its capacity by buying additional equipment, hiring more employees and possibly seeking new customers, although the latter seems questionable unless the firm is able to increase production sufficiently to enter into long term utility contracts. There are risks involved in this adjustment. The firm's owners believe that a larger operation would most certainly require unionization which would add to its costs in several ways. Welfare costs of unions are $.40 per ton and union wages would need to be paid to its employees, including heavy equipment operators, mechanics, etc.

It is questionable whether the economies of large scale would offset the higher costs, and whether the additional competition for customers would be possible in a market with several large producers with years of experience and large amounts of capital. The ability to get mineral leases would involve considerable expense and competition with larger firms that apparently have leased much of the mineral rights to land in the market area, particularly the land with thick coal seams.

There may be advantages in a large scale operation that would offset some of the disadvantages. It is apparent from the data presented in Chapter III that economies exist in building treatment plants and in other control methods, the costs of which would be considerably easier to absorb for the large firm. It is reasonable to assume that other operating economies exist at larger output levels, although we do not know at what output levels, or at what rate these economies occur in coal stripping operations. Yet even with its appeal, a significant change in size is a most unlikely adjustment for the firm, particularly since the firm is opposed to an enlargement of such a scale.

The recent experience of the firm may provide a solution to its acid control cost difficulties in that market prices of coal have been forced up due to many factors and the rising prices have been <u>partly</u> passed on to the target mine. The rise in price to the dominant firm apparently did not filter down to the small producers in its entirety.

The firm's 1970 average revenue was greater than that for 1969. This was largely due to longer hauls with their attendant higher price per ton. Its average costs in 1970 were also higher than previous years but the price increases were large enough to offset rising costs of production for the firm. Consequently, the firm enjoyed its most profitable year of the last 9 years. Again, this is due to rising market prices which are entirely out of the control of the target mine. Part of this good fortune was the result of finding No. 7 seam coal while stripping for the No. 6a seam late in the year.

Adjustment Involving Acid Drainage Control Costs and Reclamation Costs

Besides its water treatment costs the target mine must absorb additional reclamation costs as outlined in Chapter III. Its adjustment to these costs and the market effects associated with higher reclamation costs resemble the adjustment described above relative to water treatment costs. Since it is difficult to dis-associate the two kinds of programs, we have illustrated the additional cost to the firm of the least expensive water program and reclamation program by shifting the average cost function upward by the combined cost of the two for the years 1965 and 1970. We have made a similar shift using the most expensive techniques of water control and reclamation. The former are shown in Charts 9 and 10, the latter in Charts 11 and 12. The least cost combination is about \$.11 per ton, the most expensive combination is about \$.41 per ton.

With no additional increases in its market price the firm could have increased output to achieve its

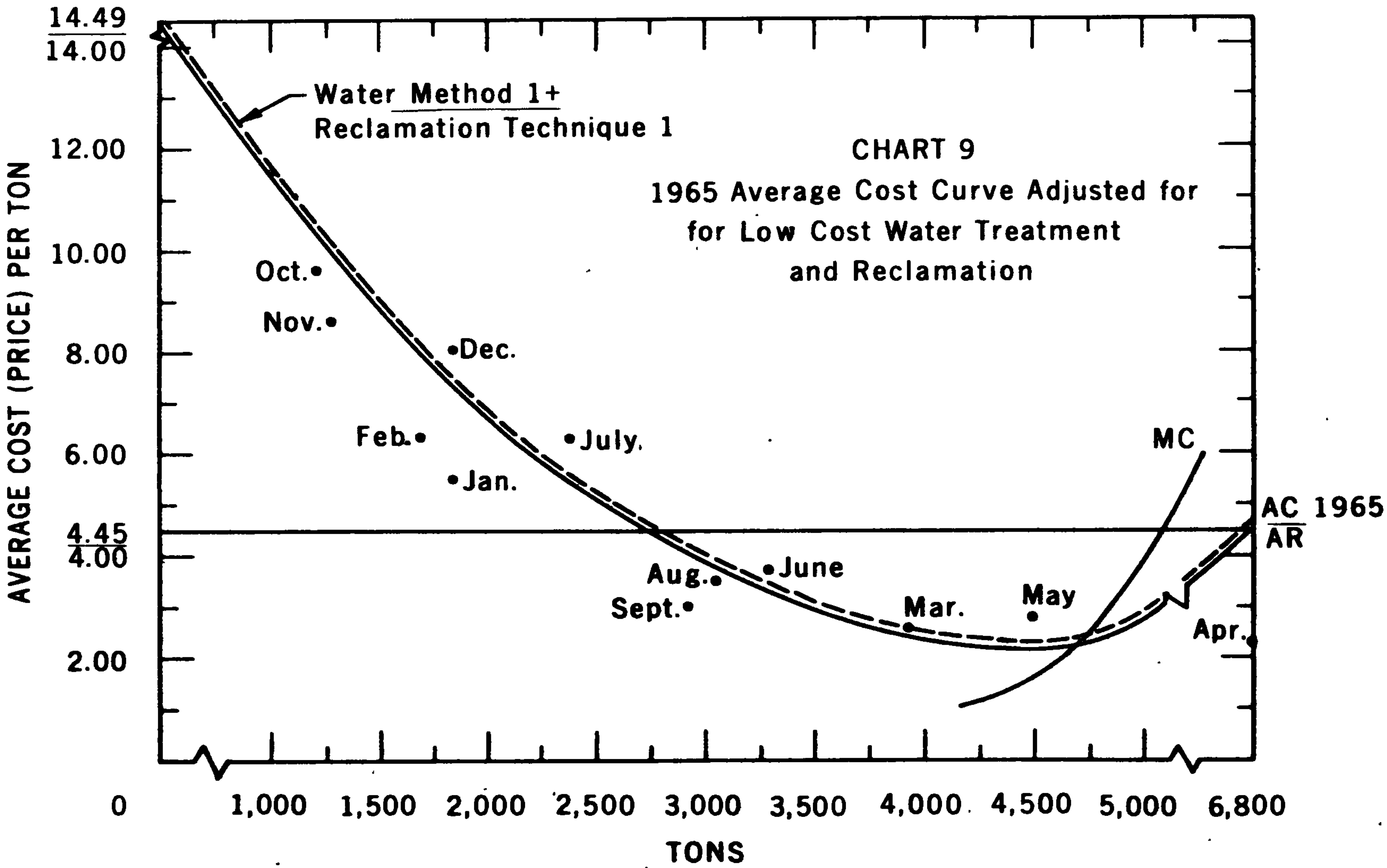
CHART 9
1965 Average Cost Curve Adjusted for
for Low Cost Water Treatment
and Reclamation
Water Method 1+
Reclamation Technique 1
AVERAGE COST (PRICE) PER TON
14.49
14.00
12.00
10.00
8.00
6.00
4.45
4.00
2.00
0
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
6,800
TONS
Oct.
Nov.
Dec.
Feb.
Jan.
July.
Aug.
Sept.
June
Mar.
May
Apr.
MC
AC 1965
AR

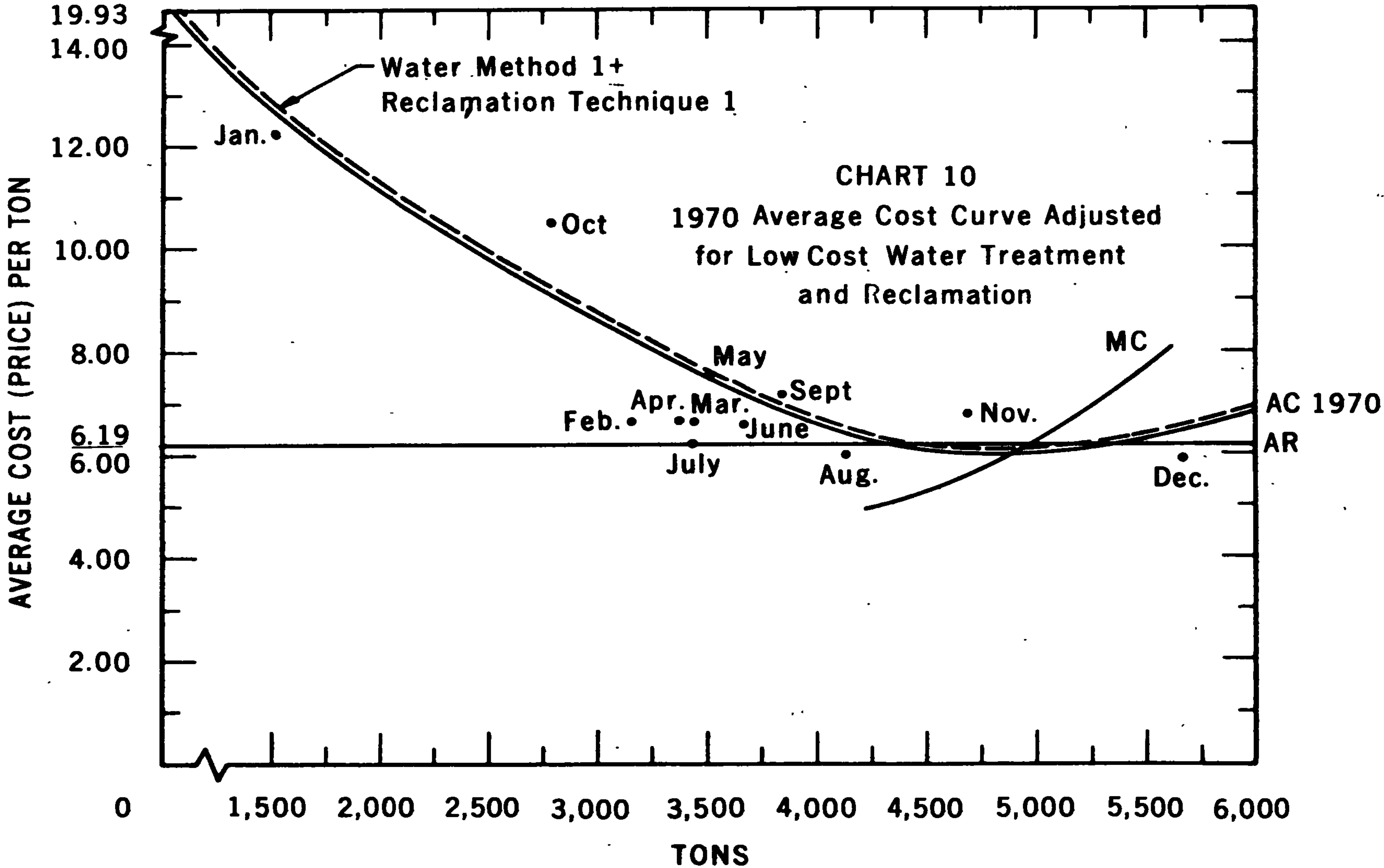
CHART 10
1970 Average Cost Curve Adjusted
for Low Cost Water Treatment
and Reclamation
Water Method 1+
Reclamation Technique 1
AVERAGE COST (PRICE) PER TON
19.93
14.00
12.00
10.00
8.00
6.19
6.00
4.00
2.00
0
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
5,500
6,000
TONS
Jan.
Oct
May
Sept
Apr.
Mar.
Feb.
June
July
Aug.
Nov.
Dec.
MC
AC 1970
AR

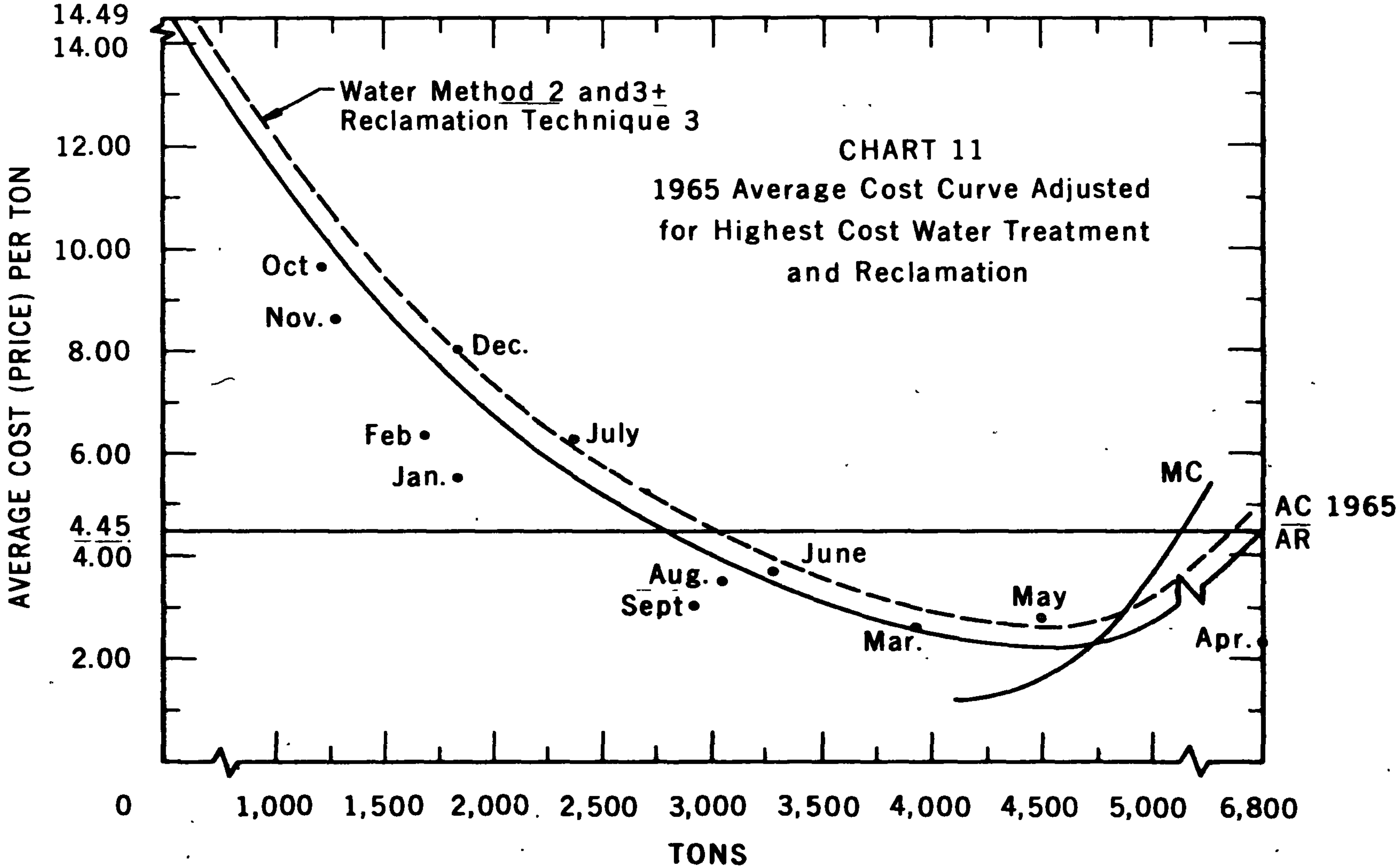

CHART 11
1965 Average Cost Curve Adjusted for Highest Cost Water Treatment and Reclamation

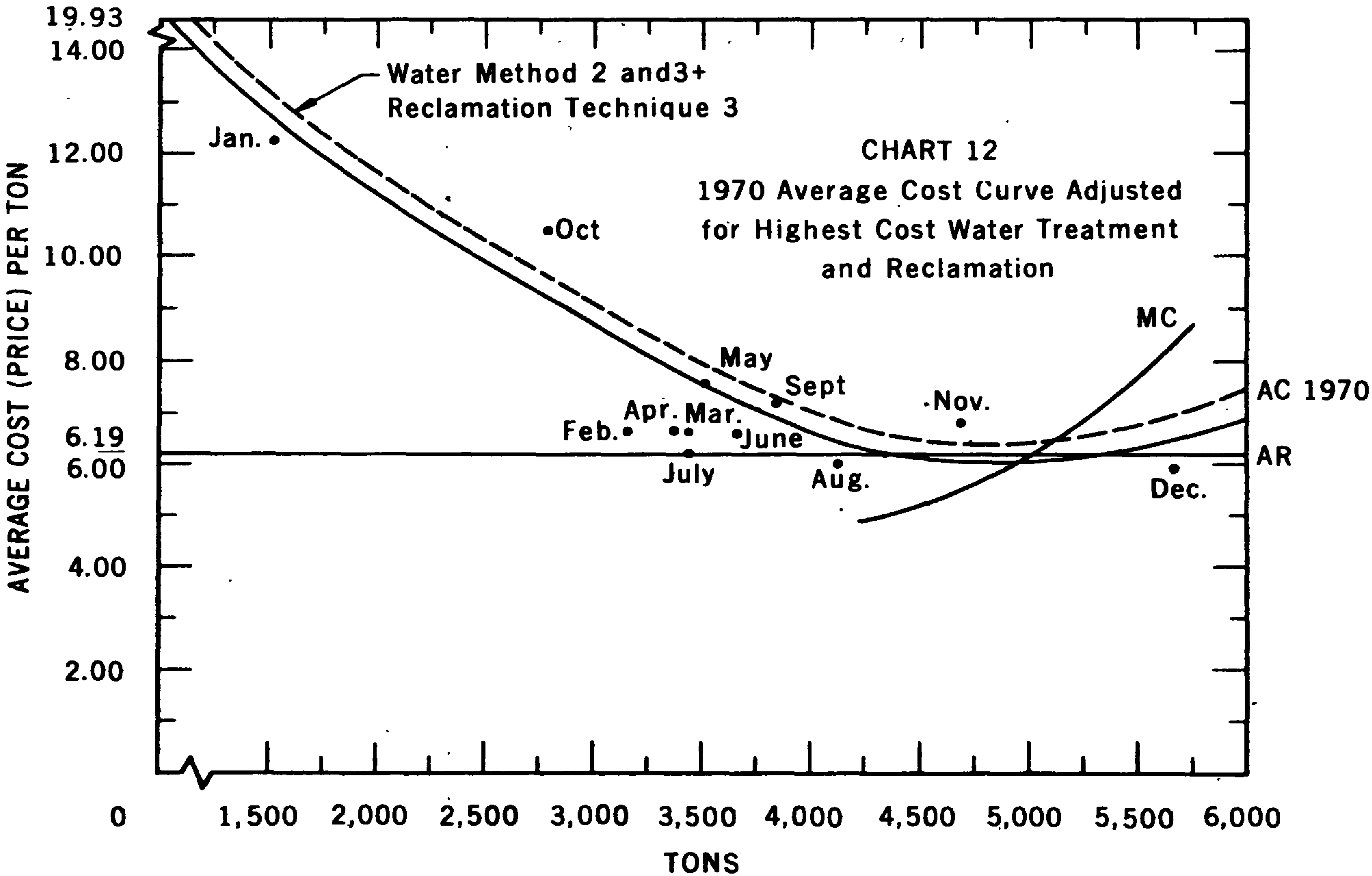
CHART 12
1970 Average Cost Curve Adjusted for Highest Cost Water Treatment and Reclamation
Water Method 2 and3+ Reclamation Technique 3
AVERAGE COST (PRICE) PER TON
19.93
14.00
12.00
10.00
8.00
6.19
6.00
4.00
2.00
0
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
5,500
6,000
TONS
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept
Oct
Nov.
Dec.
MC
AC 1970
AR

profit maximizing output level of 5113 tons per month in 1965 to absorb these costs. If its profit margin was very small as in 1967 and it was producing close to its approximate short-run capacity limit, there is little likelihood that it could absorb even $.11 per ton cost and maintain a profitable position. Again, the additional expense of $.41 associated with the more thorough water and reclamation programs could have been absorbed only in 1961 and 1970. In any other year of the firm's past operations, these costs could not have been absorbed without generating large losses as indicated by the profit data shown earlier in Tables 14 and 15.

As was suggested earlier, if the firm could shift its average cost function down through improved technology or with a change in scale of operation, these costs could be absorbed. There is no chance that these costs can be passed forward to the coal buyer unless market prices are forced up by the dominant firm.

If the additional water treatment and reclamation programs are enforced for all firms, there is still a substantial probability that the smaller firms will be unable to adjust profitably because of the greater economies enjoyed by the larger producers in treatment and reclamation and the rapidly rising marginal costs assumed to be typical of the target mine and firms similar to it. Should coal prices stabilize or begin to fall, the smaller producers who are unable to make technological adjustments or increase their scale of operations with the attendant economies of scale will go out of business. The additional coal output needed in the industry will likely be supplied by the larger firms, a continuation of the recent 10 year trend in the southeast Ohio coal market.

CHAPTER VI

SUMMARY AND CONCLUSIONS

General Summary and Conclusions

From our detailed analysis of the target mine's operation over the past ten years several conclusions can be made about the firm's ability to cover the potential costs of acid drainage pollution. Although the firm did not violate the Ohio water quality laws since the streams in the area were generally exempt from the laws, the firm did contribute additional quantities of acidic water into already badly deteriorated major streams. Consequently, the firm has no acid drainage control program or expenditures for its control. The firm spent relatively little on reclamation compared with what it would have been required to spend to keep its reclamation current. And this was so because of the leniency with which the reclamation laws were enforced during the 1960's.

The firm's ability to absorb any additional costs of acid drainage control are limited by several factors. First, the market within which the firm sells is dominated by a large producer which has tied up the major electric utility demand for coal in a long term contract. This is a typical coal market arrangement. The target mine and most of its small competitors compete primarily for the residual demand from the electric utility at a price over which they have no control. The target mine has experienced a sporatic and limited demand from public institutions and industrial users of coal within a 50 mile radius of the mine. Second, the firm's average monthly output has never been large enough to allow the firm to operate at its most efficient average monthly output level based upon its estimated average cost functions. The target mine has, however, been operating on the downward part of its short run average cost function and could in each year studied have increased output to absorb some additional costs arising from acid drainage control or reclamation or both. Its ability to adjust in this fashion was greater in 1965 and 1969 than in 1966 or 1970.

In its most recent year of production during which capacity output levels were nearly reached, the firm could have absorbed a minimum additional cost of acid drainage control and remained profitable. This occurred in a year in which rapidly rising prices of coal enabled the firm to enjoy profits on its coal sales for the second year in the past seven years of operation. However, in those years where considerable flexibility appeared to exist in expanding output, it is our conclusion that the firm's marginal costs would have risen quite rapidly at or near its capacity limit. This would substantially reduce its ability to expand output in the short run to absorb additional costs especially those associated with the more expensive acid drainage and reclamation programs which we have determined would be most appropriate for the firm.

A longer run adjustment of scale, improved technology, competition for thicker coal seams and other related alternatives may be possible for the firm. For example, one of these alternatives involves the construction and operation of simple, highly mobile treatment facilities which are relatively low cost and quite effective. This and other possible techniques of water management were developed and discussed in the study.

Considerable difficulty exists in making these longer-run adjustments particularly in light of management's opposition to expansion in the firm's size with its attendant costs and problems. A serious limitation facing the target mine is its inability to successfully bid for mineral rights to thicker coal seams. Leasing coal rights is apparently quite competitive with large firms having acquired rights to much of the available acreage with thick and multiple seams of coal. Small firms, like the target mine, are left with the thin, often single seam acres. Mining such seams results in low productivity because the coal yield per ton of overburden moved is small. With losses having occurred in five of its last seven years of operation, the risks associated with any substantial change from past experiences and operations are considerable in the minds of management.

In the study no attempt was made to precisely estimate or simulate long-run adjustment alternatives. Thus, it would be speculation to project the specific outcome from any particular long-run adjustment the firm might attempt.

Implications of the Study

It is difficult to accurately forecast the future demand for coal. Even with the recent shortages of supply and rising prices, there has been a considerable easing of demand pressure in national coal markets over the past several months. This has resulted in the decline of market prices in some areas with a further decline anticipated by officials of one of the largest producers with whom we talked.

The experience of the 1960's thus may reappear in the southeast Ohio coal market. The trend toward greater concentration in the industry as illustrated by the data in Appendices 3, 4, and 5 is likely to continue. From the experience of the target mine and the fact that the dominant producers apparently operate successfully on a target profit basis, i.e., they attempt to achieve $1.00 per ton profit in their contracts, it would appear that the smaller firms are less efficient and have considerably higher average costs and lower productivity operations than the large firms as suggested by the data in Table 20. We have no specific knowledge of the cost functions of large firms. We simply assume that their costs are lower due to economies of scale. And we know there are significant economies in acid drainage control techniques and in reclamation techniques generally.

In a dynamic market such as the coal market we can predict little from our historical analysis of the firm. With greater concentration taking place, the dominant firm model may apply more readily in the future than during the study period. The individual small producer with his relatively high cost operation will likely be less able to influence his market price and less able to absorb costs of water control programs. Consequently, it is only if water quality standards are uniformly enforced on the entire coal industry in southeast Ohio that large scale acid control programs could be successful. And this is because the dominant firms can and will shift these costs forward to coal buyers. For the target mine to attempt unilaterally to control its water problem would be competitively disastrous since even a small program would destroy the small profit margin that the firm now enjoys or enjoyed in the few years when profits were positive.

Even uniform laws burden the small producers more heavily since they lack most of the economies enjoyed by large producers. Economic theory would probably suggest that the target mine go out of business. Not only is the firm not covering its external cost of acid drainage pollution, it is barely covering its internal costs of operation in most years. Were we to approximate the external costs of acid drainage caused by the target mine, it would worsen an already bad situation. Because the stockholders are also the officers of the firm who draw wages and salaries from the firm, this has not happened. Should the coal market return to its mid-1960's stagnation, the firm's demise is a real possibility. Its output would likely be replaced by larger firms with market power, and in southeast Ohio, probably by the dominant firm that thrives there now.

In effect, the individual user of products produced with coal as the energy source will likely pay for acid control programs. Since by contract the coal supplier can shift all taxes and other costs incurred in the production process to the electric utilities, the user of electricity will absorb a large part of any cost forced on the coal producers. Utilities are absorbing more and more of our coal output so this possibility is likely to continue indefinitely.

The market system as it exists for coal in southeast Ohio is likely to be a very unfair distributor of the burden for cleaning up acidic streams, unless we accept greater concentration in the coal industry as a desirable effect. A concomitant social decision about the displacement of employees from small firms must at some future time also be made. However, if market prices of coal continue rising and high cost operations like the target mine make profits then it may be the opportune time for the public to attempt to solve acid mine drainage pollution. On the basis of our conclusions the cost of such programs will be readily passed on to electric utilities and other coal users and the move toward greater concentration in the coal industry might be less than it would have been during the early and mid-1960's. However, even with rising prices (with or without water quality programs), it is likely that market concentration in coal production in southeast Ohio will continue in the future such as that which occurred during the past decade.

APPENDIX 1

SUMMARY OF SURFACE MINE LAWS IN EFFECT IN VARIOUS STATES, APRIL, 1967

State		Coverage	Number Of Agencies Administering Laws	License Requirements		Penalty For Failure To Obtain License	Bond Required	
				Basic Fee	Additional Fee Per Acre		Minimum	Additional Bond Per Acre
Ill.	93 Ill.Stat. Ann.180	All minerals	1	(1)	None	$50-$1,000 fine	$1,000	$200 over 5 acres
Ind.	Ind.Stat.Ann. 46-1501	All minerals	1	(2)	None	$1,000-$5,000 fine	$2,000	$300 over 5 acres
Ky.	Ky.Rev.Stat. 350	Coal and clay	2	$50	$25/acre to be affected by operation	$100-$1,000 fine + $100-$1,000/day violation continues	$2,000	$100-$500
Md.	Art.66C Md. Code Ann.	Coal	2	100	$30/acre[3]	$5,000-$10,000 fine	1,600	$200
Ohio	Ohio Rev.Code 1513	Coal	2	75	$15/acre of land to be affected in license year	$300-$1,000 fine	2,000	$300

APPENDIX 1--CONTINUED

State	Code Citation	Coverage	Number Of Agencies Administering Laws	License Requirements		Penalty For Failure To Obtain License	Bond Required	
				Basic Fee	Additional Fee Per Acre		Minimum	Additional Bond Per Acre
Pa.	Pa.Stat.Ann. Title 52, §681 (anthracite) Title 52, §1396 (bituminous)	Coal	2	300	None	$5,000-10,000 fine or 6 mos. imprisonment or both	$5,000	$500
Va.	Va.Code.Ann. §45.1-162	Coal	2	150	None	Maximum $1,000 fine or 1 yr. imprisonment or both	2,500	$75
W.Va.	W.Va. Code Ann. §2461	All minerals	1	100	$30/acre[4]	$100-$1,000 fine or 6 mos. imprisonment or both	2,500	$100-$500

APPENDIX 1--CONTINUED

State	Maps & Reclamation Plan Required	Backfilling & Grading Requirements	Replanting Requirements	Substitution Of Lands To Meet Reclamation Requirements Permitted	Mining & Reclamation Reports Required	Penalty For Failure To Reclaim		Special Reclamation Fund Established
						Forfeiture Of Bond	Denial Of New Permit	
Ill.	Yes	(5)	Yes	Yes	Yes	Yes	No	No
Ind.	-do-	(6)	-do-	-do-	-do-	-do-	Yes	-do-
Ky.	-do-	(7)	-do-	-do-	-do-	-do-	-do-	Yes
Md.	-do-	(8)	-do-	No	-do-	-do-	-do-	-do-
Ohio	-do-	(9)	-do-	Yes	-do-	-do-	-do-	-do-
Pa.	-do-	(10)	-do-	No	-do-	-do-	-do-	-do-
Va.	-do-	(11)	-do-	Yes	-do-	-do-	-do-	-do-
W.Va.	-do-	(12)	-do-	No	-do-	-do-	-do-	-do-

(1) Variable, depending upon acres to be disturbed, i.e. 10 acres--$50 basic fee plus $11.50 X number of acres between 2 and 10 acres annually.

(2) Variable, depending upon acres to be disturbed, i.e. 10 acres $200 fee, 100 or more acres $500 fee annually.

(3) Fee deposited in Bituminous Coal Open Pit Reclamation Fund.

(4) Fee deposited in special reclamation fund.

(5) Grade peaks and ridges to a rolling topography; construct earth dams in final cuts; bury acid-forming materials; construct fire lanes and access roads in afforested land.

APPENDIX 1--CONTINUED

(6) Peaks and ridges must be struck to a rolling topography adjacent to public highways; construct dams in final cuts; bury acid-forming materials.

(7) Eliminate spoil peaks; grade to original contour; backfill highwalls; bury acid-forming materials; fill depressions; impound run-off water; and, remove refuse.

(8) Grade spoil banks to reduce depressions to a surface which restores terrain to as near normal as is satisfactory to State agency; impound water; bury acid-forming materials.

(9) Grade peaks and ridges to rolling topography; construct dams to impound water; bury acid-forming materials; impound run-off water; construct fire lanes or access roads.

(10) Grade peaks and depressions to a rolling topography; construct access roads; bury refuse and debris; impound water for lakes or ponds where approved.

(11) Grade peaks and ridges to gently rolling topography; grade surface to preserve existent access roads; grade loose coal and debris; impound water where approved.

(12) Grade peaks and ridges to a rolling topography; impound run-off water; bury acid-forming materials; construct ponds and lakes.

Source: Surface Mining and Our Environment, U.S. Department of Interior, p. 120.

APPENDIX 2

SOUTHEASTERN OHIO PRODUCTION (SUPPLY)
(In Thousands of Tons)

Year	U	S	Total	Price	Seam	U	S	Total	Price	Seam
			Athens					Hocking		
1960	259.1	25.1	284.2	$4.56	6,7	12.6	47.9	60.6	$4.01	6,6a,7
1961	194.9	40.1	235.0	$4.49	6,7,8	6.6	48.4	54.9	$3.77	6,6a,7
1962	209.7	34.2	243.9	$4.70	6,7,8	5.9	73.0	78.9	$3.91	
1963	153.0	29.6	182.6	$4.41	6,7,8	7.2	74.8	82.0	$3.84	5,6,6a
1964	128.0	20.7	148.7	$3.88	6,6a,7	6.8	64.2	71.0	$3.58	5,6,6a,7
1965	112.7	30.4	143.2	$3.69	6,7	2.6	101.5	104.1	$3.54	5,6,6a,7
1966	95.1	4.7	99.7	$3.88	7	2.9	75.7	78.6	$3.97	6,6a,7
1967	100.3	19.5	119.8	$4.02	7	1.0	59.0	60.0	$3.67	6,6a,7
1968	70.0	158.7	228.7	$3.91	7,8		129.8	129.8	$3.88	6,6a,7
1969	48.1	65.5	113.4	$4.05	7,8	.1	92.3	95.4	$3.78	6,6a,7
			Jackson					Meigs		
1960	44.6	354.0	398.7	$3.70	4,4a,5	45.7	149.9	195.6	$3.06	8,8a
1961	42.8	252.1	294.9	$3.81	4,4a,5,6	48.8	185.2	234.0	$3.10	8,8a
1962	45.2	249.7	294.8	$3.71	5,6,6a	57.7	50.1	245.8	$2.64	8,8a
1963	49.8	348.0	397.8	$3.79	4,4a,5,6	54.5	296.3	350.8	$3.14	8,8a
1964	47.6	514.2	561.9	$3.73	4,4a,5	37.1	556.2	593.3	$2.85	8,8a
1965	46.4	558.0	604.3	$3.82	1,4,4a,5	23.0	184.4	207.5	$3.56	8a
1966	32.8	808.3	841.1	$3.81	4a,5	26.5	62.0	32.7	$3.38	8a
1967	37.7	944.4	983.2	$3.52	4a,5	18.8	50.4	69.2	$3.34	8,8a

APPENDIX 2--CONTINUED

Year	U	S	Total	Price	Seam	U	S	Total	Price	Seam
1968	32.6	876.9	907.5	$3.29	4,4a,5	10.0	39.0	50.0	$3.03	8,8a
1969	77.2	914.4	991.7	$3.58	4a,5	12.5		12.5	na	8a
			Morgan					Muskingum		
1960	1.6	2243.4	2245.0	$3.28	9	164.5	427.1	591.6	$2.90	6,7,9
1961	.9	2300.1	2301.0	$3.25	9	72.0	35.4	107.3	$4.15	5,6,7
1962	.8	2222.7	2223.5	$3.18	9	70.1	195.7	269.7	$3.20	6,9
1963	.8	2474.9	2475.7	$3.07	9	78.9	28.8	107.7	$4.00	5,6,7
1964	1.0	1869.1	1870.1	$2.99	9	71.7	46.3	117.9	$4.22	6,7
1965	1.1	1800.2	1801.2	$3.24	9	67.2	65.2	132.4	$4.36	6,7
1966	.7	1379.3	1380.0	$3.01	9	31.3	228.1	259.4	$3.39	6,7,9
1967	.7	1019.6	1020.3	$3.26	9	120.7	579.1	699.8	$3.31	6,9
1968	.5	790.2	790.7	na	9	62.7	1988.1	2050.8	$3.41	6,8,9
1969	.7	824.9	825.6	na	9	52.6	2718.0	2770.6	$3.68	9
			Noble					Perry		
1960	.1	1955.7	1955.7	$2.54	8,9	32.3	1537.6	1569.9	$3.91	5,6
1961	.1	1490.5	1490.6	$2.86	8,9	27.4	1656.9	1684.4	$3.79	5,6
1962	.0	1680.1	1680.0	$2.58	8,9	81.5	1850.7	1932.2	$3.77	5,6
1963	.3	1803.6	1803.6	$2.78	8,9	235.4	1796.3	2031.7	$3.76	5,6
1964	.4	2678.7	2679.1	$2.73	8,9	321.3	1875.5	2196.8	$2.86	5,6
1965	.0	2978.1	2978.5	$2.42	8,9	372.0	1720.3	2092.4	$3.88	6
1966		2187.1	2187.1	$3.17	8,9	489.5	1636.8	2126.3	$3.91	6
1967		2068.7	2068.7	$3.32	8,9	797.3	1358.6	2156.1	$3.88	6

APPENDIX 2--CONTINUED

Year	U	S	Total	Price	Seam	U	S	Total	Price	Seam
1968		2379.5	2379.5	$3.42	9	1729.7	1371.8	3101.5	$4.08	6
1969		2576.5	2576.5	$3.74	9	2570.5	733.2	3303.7	$4.30	6
			Vinton					Washington		
1960	50.6	204.1	254.5	$4.15	3,4,6		95.1	95.1	na	9
1961	42.7	108.4	151.1	$4.17	4,4a,6		74.1	74.1	na	9
1962	48.3	58.7	107.0	$3.87	3,4,5,6		37.4	37.4	na	9
1963	27.3	25.2	52.5	$4.09	3,6		6.0	6.0	na	9
1964	26.2	134.6	160.8	$3.62	3,4a		2.8	2.8	na	8
1965	17.7	123.2	140.9	$4.05	4a,5,6		116.7	116.7	na	9
1966	14.9	140.5	155.4	$3.86	4a,5,6		200.1	200.1	na	8,9
1967	5.2	221.9	227.1	$4.23	4a,5,6		177.4	177.4	na	8,9
1968	5.2	221.6	226.8	$4.19	4a,5,6		106.6	106.6	na	8,9
1969	1.4	285.3	286.8	$4.23	4a,5,6		117.3	117.3	na	8

			TOTALS--S.E. Ohio					TOTALS--Ohio		
Year	U	%	S	%	Total	U	%	S	%	Total
1960	611.2	.067	7039.8	.933	7651.0	19172.0	.271	24724.5	.729	33896.5
1961	436.2	.066	6191.0	.034	6627.2	8498.9	.267	23234.8	.733	31773.7
1962	519.2	.075	6452.0	.925	6971.2	9326.4	.274	24684.4	.726	34010.8
1963	606.7	.081	6883.5	.919	7490.2	10524.2	.285	26392.5	.715	36916.7
1964	640.1	.076	7762.2	.924	8402.3	10828.8	.289	26561.7	.711	37390.5

APPENDIX 2--CONTINUED

Year	U	%	S	%	Total	U	%	S	%	Total
1965	643.1	.077	7678.1	.923	8321.2	11287.7	.287	28043.8	.713	39331.6
1966	693.8	.094	6666.6	.906	7360.3	13106.7	.304	29961.7	.696	43068.4
1967	1081.8	.143	6498.6	.857	7580.4	15176.9	.331	30714.7	.669	45891.6
1968	1910.8	.192	8056.2	.808	9967.0	16334.1	.338	31952.8	.662	48286.9
1969	2763.2	.245	8507.5	.755	11270.6	18618.3	.364	32574.6	.636	51193.0

1. Seam underlined is largest percentage seam by visual inspection.
2. Price is F.O.B. mine.

Source: Division of Mines Annual Report, Ohio Department of Industrial Relations, 1960-1969.

APPENDIX 3

COAL PRODUCTION BY SIZE OF FIRM, U.S., 1960-70

Year	Produced ≤ 50,000 Tons Per Year		Produced More Than 500,000 Tons Per Year	
	% of Mines	% of Output	% of Mines	% of Output
1960	.858	.155	.025	.493
1961	.859	.156	.025	.504
1962	.856	.160	.026	.506
1963	.845	.151	.028	.529
1964	.832	.144	.031	.549
1965	.818	.136	.035	.572
1966	.791	.128	.041	.579
1967	.756	.107	.047	.591
1968	.733	.102	.051	.585
1969	na	na	na	na
1970	na	na	na	na

Source: Bituminous Coal Data (Washington: National Coal Association, 1967 and 1969 editions).

APPENDIX 4

S.E. OHIO CONCENTRATION IN PRODUCTION
(In Thousands Of Tons)

	Total Production In County		Number 1 Firm			Number 2 Firm			Number 3 Firm			Sum of Three Firms
	U*	S	U	S	%	U	S	%	U	S	%	%
Athens												
1960 (18)**	259.1	25.1	157.2		.553	54.7		.192		19.3	.068	.813
1968 (12)	70.0	158.7		152.8	.668	30.6		.134	25.5		.111	.913
1969 (6)	48.1	65.5		41.3	.363	30.3		.265		21.8	.186	.814
Hocking												
1960 (18)	12.6	47.9		26.6	.440		5.3	.088		4.6	.074	.602
1968 (9)	10.0	129.8		44.6	.344		21.1	.163		18.7	.144	.651
1969 (8)	.1	92.3		21.5	.221		18.7	.189		17.3	.179	.589
Jackson												
1960 (27)	44.6	354.0		114.3	.289		66.6	.167		66.6	.166	..620
1968 (19)	32.6	876.9		276.1	.304		151.1	.166		102.4	.112	.582
1969 (20)	77.2	914.4		256.8	.258		210.8	.212		168.2	.170	.640
Meigs												
1960 (14)	45.7	149.9		135.8	.693	12.6		.064	12.6		.063	.820
1968 (3)	10.0	39.0		24.0	.489		15.0	.305		10.0	.204	1.000
1969 (1)	12.5		12.5		1.000							1.000
Morgan												
1960 (4)	1.6	2243.4		2231.8	.994		11.6	.005	1.0		.001	.999
1968 (2)	.5	790.2		790.2	.995		.52	.005				1.000
1969 (3)	.7	824.9		784.0	.951		40.9	.048		.70	.001	1.000

APPENDIX 4--CONTINUED

	Total Production in County		Number 1 Firm			Number 2 Firm			Number 3 Firm			Sum of Three Firms
	U	S	U	S	%	U	S	%	U	S	%	%
Muskingum												
1960 (17)	164.5	427.1		209.0	.353		188.5	.319	93.4		.157	.829
1968 (15)	62.7	1988.1		1783.1	.869		106.5	.052		44.5	.021	.942
1969 (9)	52.6	2718.0		2244.9	.810		252.6	.091		139.6	.050	.951
Noble												
1960 (11)	.1	1955.7		898.5	.459		484.2	.248		167.5	.085	.792
1968 (8)		2379.5		745.4	.313		794.9	.292		454.0	.191	.796
1969 (7)		2576.5		1473.6	.534		435.3	.158		316.4	.115	.807
Perry												
1960 (22)	32.3	1537.6		1207.9	.769		129.9	.082		42.7	.027	.878
1968 (14)	1729.7	1371.8	1717.1	1137.9			91.1	.029		46.3	.015	.964
1969 (13)	2570.5	733.2	2554.9	432.8			110.5	.033		89.5	.027	.964
Vinton												
1960 (17)	50.6	204.1		87.5	.343		58.1	.228	16.6		.063	.634
1968 (10)	5.2	221.6		118.7	.522		35.4	.155		16.5	.071	.749
1969 (7)	1.4	285.3		124.9	.433		49.2	.171		44.6	.154	.758
Washington												
1960 (2)		95.1		52.9	.556		42.2	.444				1.000

APPENDIX 4--CONTINUED

	Total Production in County		Number 1 Firm			Number 2 Firm			Number 3 Firm			Sum of Three Firms
	U	S	U	S	%	U	S	%	U	S	%	%
1968 (1) 1969 (1)		106.6 117.3		106.6 117.3	1.000 1.000							1.000 1.000

*U = underground; S = surface mining includes strip and auger mining.

**Numbers in parentheses are number of producers.

Source: Division of Mines Annual Report, Ohio Department of Industrial Relations, 1960-1969.

APPENDIX 5

SUMMARY OF S.E. OHIO CONCENTRATION IN PRODUCTION
(In Thousands of Tons)

	Total of 10 Southeastern Ohio Counties						Total Ohio	
	1960	%	1968	%	1969	%	1969	%
Total production	7,651.0		9,966.9		11,270.6		51,193.0	
Number 1 Firm	5,121.6	.669	6,896.5	.692	8,064.5	.716	12,626.4	.247
Number 2 Firm	1,054.3	.138	1,143.6	.115	1,148.3	.102	5,823.3	.114
Number 3 Firm	424.3	.055	718.8	.072	798.2	.071	5,220.2	.102
Sum of three firms	6,600.1	.863	8,758.9	.878	10,011.0	.888	23,669.9	.463

Source: Derived from Appendix 1.

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13. ABSTRACT

This report analyzes the quantity and quality of acid mine drainage attributable to current operations of a small strip mine firm and from abandoned underground and surface mines, estimates the costs to the firm in order to meet current legal requirements, estimates the effects of these costs on the firm's level of output and its ability to pass costs forward to consumers or back to mineral lease holders and projects the impact of alternative drainage control programs. The analysis integrates physical and legal factors with economic analysis of the demand and supply schedule for the firm.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Water Quality Standard						
Pollution Abatement						
Mine Drainage Abatement						
Water Treatment						
Reclamation						
Industry Demand Function						
Firm Demand Function						
Firm Supply Function						

C

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