TOPSOIL ROCK REMOVAL TECHNOLOGY

FINAL REPORT

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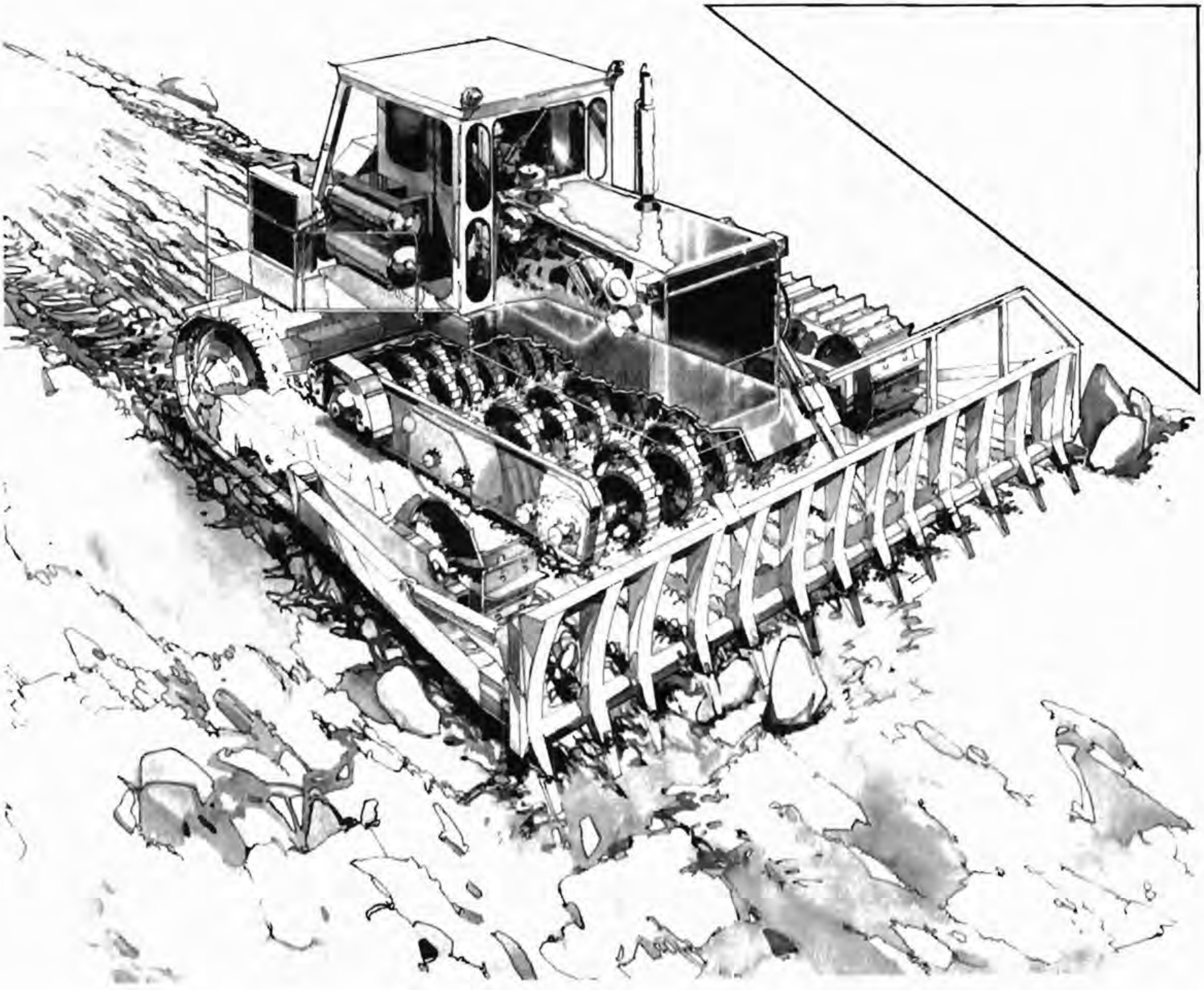

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This report summarizes a study conducted to determine the state of the art of various rock removal systems and their capabilities. The objective of the study was to determine if currently manufactured equipment can adequately accomplish rock removal in surface mine reclamation applications. Evaluations of state reclamation regulations, with regard to topsoil rock content, were made to determine the rock removal requirements. The major categories of equipment studied are rock pickers and rock rakes.

The impact of rock removal implementation on the reclamation operations is discussed in detail.

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FOREWORD

This report was prepared by Skelly and Loy, Engineers and Consultants, 2601 North Front Street, Harrisburg, Pennsylvania, under USBM Contract Number J0285023. The contract was completed under the Mining Environmental Research Program. It was administered under the technical direction of Spokane Mining Research Center with Mr. Thomas Brady as Technical Project Officer. Ms. Darlene Wilson was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period October 1, 1978 to September 30, 1979. This report was submitted by the authors on October 31, 1979.

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INTRODUCTION

INTRODUCTION

Surface mining in the United States is one of the most productive and safest methods of obtaining coal; however, in spite of being safer than underground mining, surface mining has evoked tremendous criticism due to the disruption of large areas of land. Previously fertile farmland turned into unsightly and unproductive wasteland is a serious reclamation problem. The disturbed soil may contain too many large rocks and will not be as productive as the original soil. Farming in areas where no care has been taken to remove large rocks may result in damaged farm equipment and smaller, sometimes less desirable harvests.

To ensure that the soil maintains its productivity and permeability, many states have enacted laws and policies to control the size and quantity of rock in the topsoil. On the federal level, the Office of Surface Mining (OSM) has established strict regulations governing revegetation of the reclaimed areas. Removing rocks from the topsoil is a fairly easy task; however, maintaining productivity levels is much more complex, requiring years of monitoring. The physical and chemical properties of the undisturbed soil can be characterized prior to mining, but the changes that occur during mining and reclamation are not completely understood. Until these changes are understood, maintaining productivity levels will continue as a reclamation problem.

In most large surface mines, scrapers are used for topsoil removal, stockpiling, and redistribution. Because of their availability, flexibility to load and haul different soil horizons, and maneuverability, scrapers are used extensively in the mining industry. However, compaction caused during pickup and placement of the soil is detrimental to the agricultural root zone. When scrapers place clayey subsoil, they can also cause internal soil drainage problems.

After topsoil redistribution, the soil must be prepared for revegetation. If there are too many large rocks in the topsoil, graders may be used to eliminate them prior to revegetation. Since this method does not penetrate the soil, it is often inadequate and does not comply with many regulations. When deeper penetration is desired, rock rakes attached to dozers are employed. Rakes can eliminate large rocks to depths of 18 inches and deeper, but do not remove the smaller rocks less than 6 inches in size. While the spacing of tines on rock rakes is easily adjustable, if the tines are spaced too close, the soil will be pushed in front of the dozer and rocks will not be eliminated.

Since graders and rock rakes are not totally effective for rock removal, some mining companies have elected to use rock pickers. However, their use by the mining industry is limited. Rock pickers are not classified as mining equipment, and are generally sold as farming equipment.

Why aren't rock pickers popular within the mining industry? Often the topsoil is so plentiful and free of large rocks there is simply no need for them. In addition, regulations governing reclamation generally have made no mention of the quantity of rock in the topsoil. Since rock pickers are generally associated with the farming industry, mining companies may not have explored the potentials of rock removal devices.

The following sections of the report will carefully outline the extent of the rock problem throughout the United States; discuss in detail the legal requirements that affect the reclamation process; analyze the "State of the Art" of current rock pickers including their physical limitations; present an extensive economic and sensitivity analysis; describe the environmental effects that may take place; introduce some new concepts and methods of rock removal; and, finally, detail the benefits that can result from introducing rock pickers into the mining industry.

TOPSOIL ROCK CONTENT INVESTIGATIONS

TOPSOIL ROCK CONTENT INVESTIGATIONS

In order to explore the feasibility of transferring topsoil rock removal technology in its present state from its agricultural origin into surface mine reclamation, nine representative mine sites were visited. By sampling rock contents of soils before and after they were affected by mining, an indication of the need for incorporating rock removal into the reclamation plans could be ascertained. In addition, these investigations would be used to deduce the capability of current rock picker technology to function in mining environments.

Having been contractually limited to nine mine visits for this study, the selection of those sites was made by stressing diversity. With the exception of four mandatory visits to mines that were affecting areas where the predominate, pre mining land use was farming, each site chosen provided a unique combination of topsoil quality, topography, climate, and method of mining. Further considerations were made of the states that had rock limitation regulations. In addition, mines using rock removal devices to improve reclamation were sought to assess successes and problems.

Each mine visit consisted of a discussion with mine operators of mining methods, availability of topsoil, overburden characteristics, reclamation equipment, amount of land reclaimed annually, average amount of time spent on reclamation each year, and any particular reclamation problems experienced at the mine. The operator would then provide a tour of his operation for a firsthand view of mining practices and rock content evaluation of the soils.

Rock content was evaluated by digging small test holes, then separating and weighing the rock and soil components. Assuming a maximum mechanical picking depth (for optimum rock removal operation) of 12 inches, the samples were examined in two stages. The percent, by volume, of rock to soil was calculated for 0-6 inches and 6 12 inches. Segregation of rocks from soil was made by considering all material passing through a one inch sieve to be soil and all that is retained to be rock. Those rocks in excess of 3 inches in their smallest dimension were weighed separately; however, in most cases this size fraction was a small portion of the total rock content. Test results for each mine are summarized in Table 1.

Mine CH 1 (area mine) is located in flat lying prime farmland of Indiana and exhibited abundant rock free loamy topsoil both before and after mining. Occasionally, this mine encountered shortages in topsoil during reclamation which prompted them to utilize a rock picker on the surface of their graded overburden prior to topsoil replacement. This mine had no rocks above 1" in diameter in its original or reclaimed topsoils.

Mine CH 2 (area mine) is situated in flat prime farmlands of central Illinois, which characteristically contain abundant, rockfree, silty soils. This mine had no rock fragments larger than 1" in diameter in its original and reclaimed topsoils.

Mine CH-3 (area mine) is affecting flat prime farmlands in southern Illinois which characteristically contain abundant, rockfree, silty soils. This mine had no rock fragments larger than 1" in diameter in its original and reclaimed topsoils.

TABLE 1

TEST HOLE RESULTS

MINE SITE	ORIGINAL ROCK CONTENT (%)			RECLAIMED ROCK CONTENT (%)		
	Hole Depth		Hole Avg.	Hole Depth		Hole Avg.
	0-6"	6-12" (1)		0-6"	6-12" (1)	
CH-1*	0	0	0	0	0	0
CH-2*	0	0	0	0	0	0
CH-3*	0	0	0	0	0	0
CH-4	5	10	7.5	5	6	5.5
CH-5	0	0	0	10 (2)	10 (2)	10 (2)
CH-6	7	13	10	9	14	11.5
CH-7	7	12.5	9.75	9	14	11.5
CH-8*	0	0	0	0	0	0
CH-9	7	10	8.5	5	7	6

* denotes mine sites in prime farmlands

(1) hole depths varied between 8 12" due to digging difficulties and topsoil thickness

(2) prior to rock picking step; after picking it is returned to 0 for all categories

Mine CH-4 (contour mine) is being developed in a mountainous, semi arid setting in New Mexico, which contained limited topsoils. The mining process manufactures soils through the degradation of decomposed sandstones. Successful revegetation was a problem in this harsh environment.

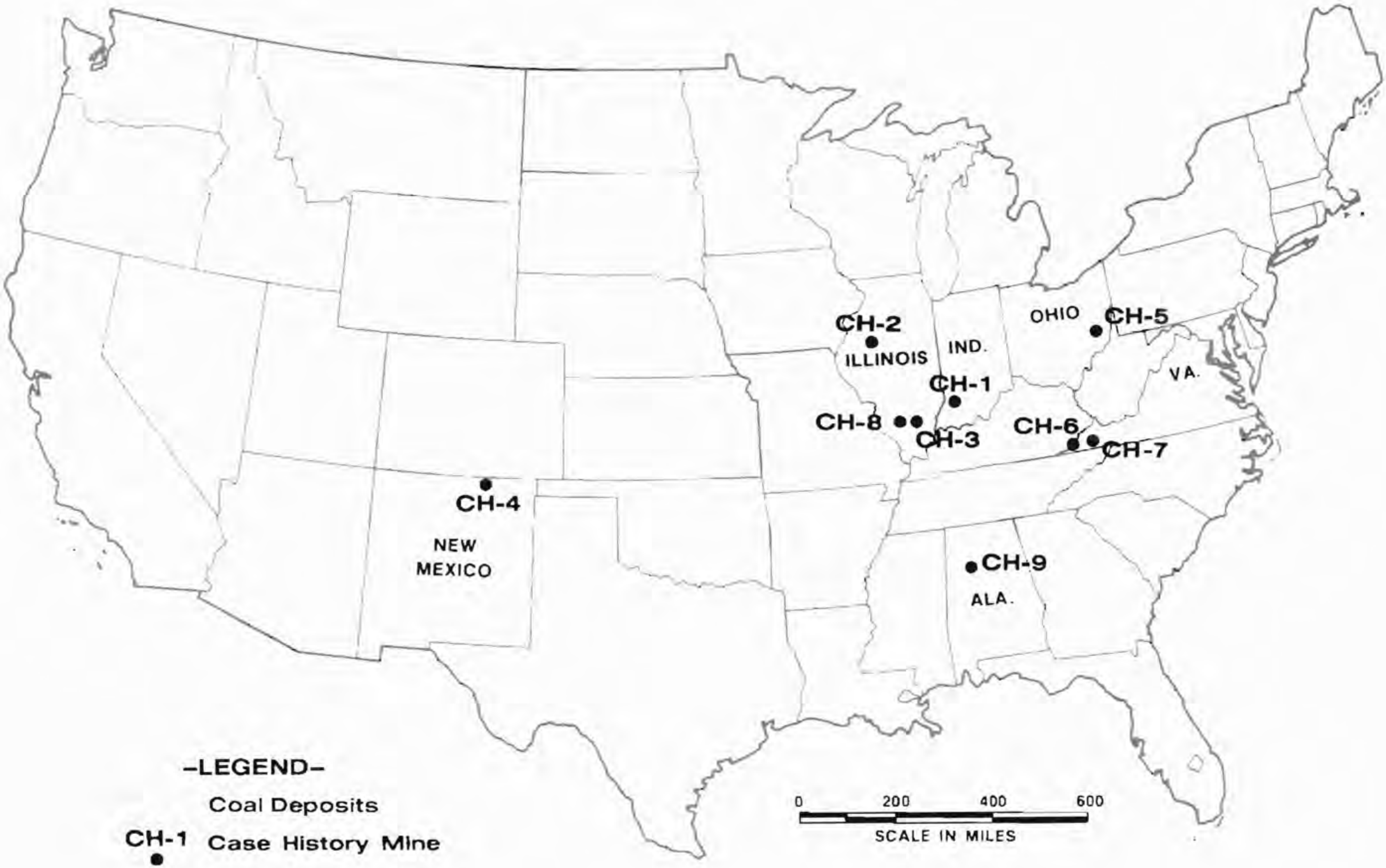
Mine CH 5 (modified area mine) is located in the rolling hills of Ohio. Rock content is a recurrent reclamation problem, which is met by employing a rock windrower and a rock picker. Loamy topsoil is abundant, yet surface rock prevalence hinders revegetation efforts.

Mine CH 6 (contour mine) is located in a mountainous section of southwestern Virginia, where topsoil is loamy, rocky, and scarce.

Mine CH-7 (mountaintop removal) is being developed in a mountainous section of southwestern Virginia, where topsoil is loamy, rocky, and scarce.

This visit to Mine CH-7 was of particular interest. In prime farm land areas, topsoil can be stockpiled and redistributed following mining. Mountaintop removal, on the other hand, is practiced in steep slope areas where topsoil is thin and poorly productive. After a mountaintop removal operation is complete, a large level surface remains and, if the topcover can be sufficiently improved, a productive farmland might be possible, where none had previously existed. Rock removal technology could figure greatly in this top cover improvement.

Mine CH-8 (area mine) is affecting flat prime farmlands in Illinois which characteristically contain abundant, rock free soils. Rock content



LOCATION MAP - MINE VISITATION SITES

FIGURE 1

was not a significant problem at this mine; however, a rock picker had previously been used in a manner similar to Mine CH 1. Topsoil at this mine was of a silty nature. This mine had no rock fragments larger than 1 inch in diameter in its original and reclaimed topsoils.

Mine CH 9 (contour mine of steeply pitching seams) is situated in Alabama. Topsoil was inherently rocky and scarce in this hilly, woodland area.

These mines are representative of mining methods and conditions nationwide. The mining techniques and equipment used at these sites are typical of current trends in mining, and the varied rock content and topsoil characteristics cover the range of the diversity present in surface coal mines across the country.

While test holes were generally less than one cubic foot in volume, they provided results that were consistent with the observed conditions exhibited in exposed cuts. The prevalence of rocks in excess of 6 inches was not prohibitive to rock picker operation at any of the mine sites. Furthermore, present day topsoil handling methods prevent the rock content of replaced topsoil from being significantly greater than the original content. It is safe to say, that even if no rock removal systems are used, no active mine will replace a topsoil media that exceeds or even approaches a 40% rock content (by volume) when using today's topsoil methods. It was observed that, in general, rock content per size gradation was decreased as a result of the mining activities. Blasting, grouser traffic, geologic unloading, weathering, and material handling affect the rocks of a mine site. When topsoil is scarce, these factors help to produce a supplemental soil media to accomplish revegetation. As for topsoil rock size degradation, this is prompted by grouser traffic, material handling, and weathering (including frost action).

One exception to the representativeness of the percentages listed in Table 1 could be for the mountaintop removal site (Mine CH 7). Being in its initial stage of development caused it to be more exemplary of a contour mine. In addition, the presence of a 50 foot thick sandy shale (which is readily degradable) as the top rock strata may have provided a top cover rock content less rocky than might be found at locations were more resistant rock types exist.

No abandoned mined sites were sampled or visited; therefore, no rockiness documentation can be provided here. However, previous experience with abandoned mined lands indicates that the worst rock content conditions will occur in areas where backfilling and reclamation were accomplished by indiscriminant overburden casting. This would preclude the presence of original topsoil, since the mining progression would initially cast the topsoils and then continue to backfill, until the blasted toprock fragments were heaped on last. All other methods allow for more burial of bedrock fragments. For the mines where remaining spoil piles represented overturned strata, normal reclamation efforts can restore the area to a condition of less than 40% rock content in the upper 6 inches of backfill.

Determination of the scope of reclamation problems on abandoned mined lands is beyond the scope of this effort; however, rock removal technology must figure heavily in improving surface cover rehabilitation, if mined lands are to be returned to agricultural uses. The nationwide extent of abandoned mined lands is shown in Figure 2.

From the mine site investigations that were conducted, it seems that the need for rock removal equipment is highly localized and dependent on regulation and post-mining land use. Under the worst of conditions, top cover should seldom exceed 40% rock content. Where topsoil can be saved and redistributed, rock content is not likely to exceed 20% rock by volume.

DISTRIBUTION OF ABANDONED COAL MINED LANDS IN THE UNITED STATES

FIGURE 2

REGULATORY ROCK REMOVAL REQUIREMENTS

REGULATORY ROCK REMOVAL REQUIREMENTS

For years surface mining was conducted without concern for future land uses. Consequently, the overburden strata were overturned, burying the original topsoil, and abundant rock fragments were introduced into the soils. The resultant deterioration of land utility has prompted the promulgation of regulations to insure that every effort is made to restore mined areas to their original conditions.

STATE REQUIREMENTS

As states became increasingly concerned with the adverse effects of surface mining they began enacting and enforcing more stringent regulations governing surface mine operations. Among the adverse effects of surface mining which were detected was "rock pollution". The contamination of the soils with an unnaturally high percentage of rocks and the prevalence of large rocks, at or near the surface, hindered revegetation efforts (especially where farming was attempted as a post-mining land use). The current tendency of regulatory legislation is to aim toward requiring mine operators to return affected land to its original condition. Thus, the states having the most rock free soil would need the most specific requlations on rock content limitations for the topsoil layer. However, it would also be evident that with proper handling these regulations should not pose a hardship on the reclamation efforts.

Table 2 provides a comparison of existing specific restrictions, implied regulations, and pending surface mine amendments. The states that are shown as having specified regulations are those defining limitations of rock size and/or percent in the topsoil layers of surface coal mine reclamation. Implied regulations are indefinite limitations pertaining to rock content in the topsoil layer. Such limitations are worded to the effect that "large rocks" will not hinder post mining land uses. The strictness of pending legislation was not discernable; however, almost all pending legislation was expected to reflect the intent of the new regulations promulgated for The Federal Office of Surface Mining (OSM).

Among the states that are monitoring topsoil rock content, the most strict regulations are found in Illinois, Indiana, Kansas, Oklahoma, and Virginia.

According to Illinois' Rule 1104, land that is suitable for row crops must be reclaimed to its original state. When available in such depth, at least 18 inches of the darkened surface soil shall be segregated and replaced. In no case shall less than 8 inches of surface soil be segregated and replaced. The total soil thickness of topsoil and subsoil must be four feet. The subsoil shall contain no more than 20% coarse material greater than 2mm in size by volume. No more than half of the coarse material may be between 3 inches and 10 inches in the greatest dimension. No fragments shall be greater than 10 inches in size.

Indiana requires that all exposed rocks larger than 6 inches in diameter shall be buried (where practicable) unless they will disintegrate in less

TABLE 2

STATE REGULATIONS ON TOPSOIL ROCK CONTENT

STATE	SPECIFIED STATE REGULATIONS	IMPLIED STATE REGULATIONS	PENDING LEGISLATION*	CURRENT POLICY
Alabama	○	●	○	Replace as was
Alaska	○	○	○	None
Arizona	○	○	●*	None
Arkansas	○	○	●*	None
California	○	○	●*	None
Colorado	○	○	●*	None
Connecticut	○	○	○	None
Delaware	○	○	○	None
Florida	○	○	○	None
Georgia	○	○	○	None
Hawaii	○	○	○	None
Idaho	○	●	○	Replace as was
Illinois	●	○	●*	No 10" rocks in top 4 feet
Indiana	●	○	○	Bury 6" rock at least 6" deep
Iowa	●	●	○	Implemented interim OSM regulations 8/78
Kansas	●	○	●	Bury 6" rocks at least 6" deep
Kentucky	○	○	●*	Replace as was
Louisiana	○	○	●*	Replace as was
Maine	○	○	○	None
Maryland	○	●	●*	Replace as was
Massachusetts	○	○	○	None
Michigan	○	○	●*	Replace as was
Minnesota	○	○	●	Requires removal of 6" rocks from surface
Mississippi	○	○	●*	None
Missouri	○	○	●*	Requires removal of excess rock

LEGEND: ● Yes ○ No

* Will Conform to Office of Surface Mining (OSM) Regulations.

TABLE 2 (Cont'd.)

STATE REGULATIONS ON TOPSOIL ROCK CONTENT

STATE	SPECIFIED STATE REGULATIONS	IMPLIED STATE REGULATIONS	PENDING LEGISLATION*	CURRENT POLICY
Montana	○	○	●*	Replace as was
Nebraska	○	○	○	None
Nevada	○	○	○	None
New Hampshire	○	○	○	None
New Jersey	○	○	○	None
New Mexico	○	○	●*	None
New York	○	○	○	None
North Carolina	○	○	○	Requires removal from tillable lands
North Dakota	○	●	●	Requires removal from tillable lands
Ohio	○	●	○	Requires removal from tillable lands
Oklahoma	●	○	●	Adopted interim OSM regulations
Oregon	○	○	●	None
Pennsylvania	○	○	●*	Replace as was
Rhode Island	○	○	○	None
South Carolina	○	○	○	None
South Dakota	○	○	○	Replace as was
Tennessee	○	●	●*	Requires removal of 6" rocks from surface
Texas	○	○	●*	Replace as was
Utah	○	○	●*	None
Vermont	○	○	○	None
Virginia	●	○	○	Replace as was
Washington	○	○	○	Replace as was
West Virginia	○	●	●*	Must remove exposed boulders from surface
Wisconsin	○	○	○	None
Wyoming	○	●	●*	Replace as was

LEGEND: ● Yes ○ No

* Will Conform to Office of Surface Mining (OSM) Regulations.

than three years. It is further specified that the buried rocks will be covered by a minimum of 6 inches of soil and in tillable land a minimum of 18 inches of soil shall cover them.

Iowa stipulates that less than 10% of the surface layer (defined as 6 inches) can contain rock fragments in excess of 3 inches.

Kansas specifies that all exposed rocks larger than 6 inches in diameter shall be buried (where practicable) unless they will disintegrate in less than three years. Buried rocks shall be covered by a minimum of 6 inches of soil.

Oklahoma recently enacted new regulations based upon the OSM interim program. They state that in areas that were formerly prime farm lands, less than 10% of the surface layer (defined as 6 inches) shall contain rock fragments in excess of 3 inches. However, once the final OSM regulatory program is implemented this restriction may be dropped.

Virginia's regulations state "The surface should be free of rocks larger than 3 inches in diameter and have 1/3 to 1/2 by weight of sand, silt, and clay sized material. Too much silt and clay, which derives primarily from shale, tends to seal overburden from rainfall. However, too much rock material is very difficult to vegetate".

Maryland is listed as having implied regulations on rock content. Its directives say that grading should attempt to minimize the presence of any large rocks in the surface.

Another implied rock content limitation exists in Tennessee, where operators must bury large rocks or place them in drainways or water retarding structures.

West Virginia merely requires that the reclaimed surface must permit the use of farm implements. This indirectly limits the presence of exposed boulders without giving any qualifying parameters.

Wyoming also omits quantitative limitations, yet cites contemporaneous restrictions on rock removal. "Trees, large rocks, and other waste material which hinder redistribution of topsoil shall be separated from the topsoil before stockpiling; if subsoil is to be used as a substitute for topsoil, all large rocks and other waste material which may hinder redistribution shall be separated before stockpiling".

In summary, Table 2 shows that only 12% of the states specify rock content limitations, while 14% only have implied rock restrictions. In total, only 26% of the states have made any commitment to rock content regulation. Even in view of the fact that 48% of all states have pending legislation, it is highly unlikely that there will be a significant national increase in rock content regulations. The states with pending laws were prompted to include rock content restrictions to comply with the interim regulatory program of OSM. Subsequently, a revised regulatory program was formulated, and its implementation will not effect a change in state legislation toward more rock content limitations.

FEDERAL REQUIREMENTS

The permanent regulatory program of the Office of Surface Mining (OSM) does not have any regulations pertaining to the size or percent by volume of rocks in a reclaimed area. However, OSM does indirectly prevent an increase in rock content by requiring that each soil horizon (distinct soil layer) be removed separately, stored separately, and replaced as they were originally. This is aimed at eliminating the possibilities of mixing sublayer rock fragments into the upper soils and of overturning the strata.

Topsoil Removal

Once vegetation is removed from a mine site, OSM requires that the topsoil must be scraped off before drilling blast holes, blasting, and/or mining is initiated. All topsoil must be removed and stored separately. In thin topsoil conditions, where the topsoil is less than 6 inches, a 6 inch layer (that includes all the available A horizon and the unconsolidated materials immediately below it) must be removed, stored and redistributed as the surface soil layer. Some exceptions can be made if it can be shown that there will be no adverse effects on full restoration of the premining qualities.

Topsoil Redistribution

After final grading and before the replacement of topsoil, OSM states that the regraded land shall be scarified or otherwise treated to eliminate slippage surfaces and to promote root penetration. If the mine operator can demonstrate that no harm will be caused to the revegetation success, scarification may be conducted after topsoil distribution. The topsoil and other materials must be redistributed in a manner that achieves an approximately uniform thickness consistant with the approved post mining land use.

Redistribution of topsoil must prevent excess compaction and erosion by wind or water prior to planting.

STATE OF THE ART OF ROCK PICKERS

STATE OF THE ART OF ROCK PICKERS

CHARACTERISTIC FORMS OF ROCK PICKERS

Many of today's rock removal devices have evolved from the potato farming business. As a result, most of the rock pickers are designed to pick rocks above 2 inches minimum diameter. Stones larger than 2 inches are removed prior to potato planting, in order to reduce the number of stones harvested along with potatoes. Table 3 lists the general specifications of currently available rock pickers. In instances where companies manufacture more than one size rock picker, only the largest models have been included in the table.

The mechanisms used in rock pickers to separate the soil and the rock can be classified into four categories: potato chain, rotating rake, rotating cage, and passive rake.

Potato Chain Rock Picker

The potato chain (Figure 3) is the most common separation mechanism used to separate rocks from soils. These rock pickers are towed behind a tractor mounted on the draft arms of a three point hitch. Power is obtained from the tractor's power take off (PTO) shaft. The rock picker consists of three basic components: the digging head, the conveying potato chain and a storage hopper.

The digging head can take two forms. It is normally either a fixed blade or a rotating rake. The fixed blade pick up method uses a steel

TABLE 3
ROCK PICKER

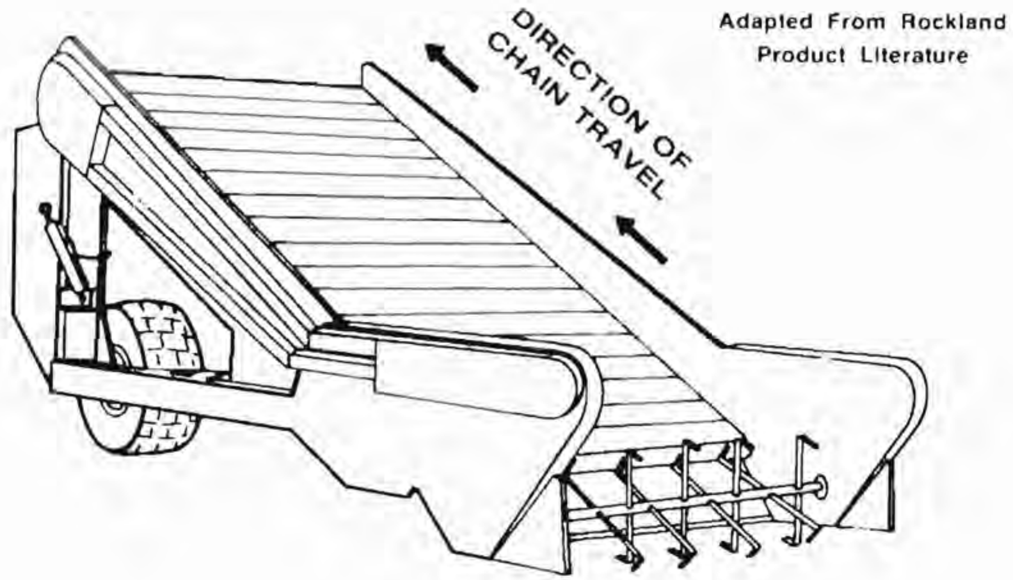
COMPANY	MODEL	HITCH TYPE	RAKE BAR	PENETRATION	MAXIMUM ROCK SIZE	MINIMUM ROCK SIZE	HOPPER CAPACITY Cu. Yd
(2) Armor Metal Products	Series E	Standard P.T.O.	Rotating	2 to 4"	200 lbs.	1 1/2"	1.2
(4) Bestland	876	Hydraulic	Fixed	2 to 3"	1000 lbs	1 3/4"	1.2
(2) Degelman Industries, Ltd.	R 570 S	P.T.O. Pull	Rotating	2 to 3"	Not Available	4"	1.0
(3) Harley Rock Picker Co.	A High Lift	P.T.O.	Rotating	2 to 3"	20"	2"	1.1
(4) Imperial Welding & Machine, Ltd.	Mel Cam 510	Hydraulic	Fixed	0	44"	3"	0.9
(2) Leon's Manufacturing Co., Ltd.	A 7500	Hydraulic	Rotating	2"	20"	2"	2.3
(1) Lockwood Corp.	Hydra lift L06630-00207	P.T.O. 540	Vibrating	8"	200 lbs.	3/4"	1.25
(2) McConnell Manufacturing Co. Inc.	Bin Type	P.T.O. Standard	Fixed	6"	10"	2"	1.5
(4) Melroe Division	8-D HiBoy	Hydraulic	Fixed	4"	200 lbs.	2"	0.9
(2) N. P. Nelson	40	P.T.O. Standard	Rotating	2 to 5"	9"	1 1/2"	.75
(1) Pratt Farms	Model B	P.T.O. Standard	Fixed	0 to 8"	24"	2"	5.0
(2) Rockland Manufacturing	Rotoveyer	3 Point Hitch	Rotary	12"	10"	2"	8.0
(2) Rock O Matic, Ltd.	8DW5	P.T.O.	Rotary	0	24"	2"	1.6
(2) Schulte	RS-H High Lift	P.T.O. or Hydraulic	Rotary	2 to 3"	28"	2"	2.4
(1) Steinman Manufacturing, Inc.	#480	Hydraulic	Fixed	2 to 4"	10"	2"	1.2
(1) Thomas Equipment, Ltd.	Hopped Type	Drawbar	Fixed	to 12"	Not Available	1 1/2"	2.0
(4) West Go	A114	Drawbar	Rotary	Not Available	24"	2 1/2"	1.1
(2) Wisconsin Rock Harvester	HD 58	P.T.O.	Rotary	2 to 4"	500 lbs.	1"	1.6

LEGEND: (1) Potato Chain (2) Rotating Rake (3) Rotating Cage (4) Passive Rake

TABLE 3 (Cont'd.)

SPECIFICATIONS

TINE ADJUSTMENT	HORSE POWER REQUIRED	SPEED OF OPERATION	WEIGHT	DUMPING HEIGHT	LENGTH	SWATH	1979 PRICE (F.O.B. Factory)
No	40	1 to 5 mph	4700#	7' 6"	13' 0"	5' 6"	$ 5,220
Yes	35	0 to 4 mph	3500#	6' 4"	10' 0"	8' 0"	$ 2,895
Not Available	70	to 5 mph	2500#	5' 0"	13' 6"	5' 0"	$ 5,546
Yes	50	2 to 4 mph	6810#	6' 0"	33' 0"	8' 0"	$11,260
No	Not Available	Not Available	1500#	13' 6"	12' 0"	5' 0"	$ 2,200
No	60	2 to 3 mph	6000#	2' 8"	16' 0"	4' 10"	$ 8,135
No	60 80	4 to 5 mph	4250#	6' 3"	21' 4"	8' 0"	$ 6,837
No	45	0 to 4 mph	3830#	6' 0"	16' 0"	8' 0"	$ 5,978
No	45	0 to 4 mph	2800#	7' 6"	17' 0"	6' 0"	$ 2,565
Yes	7	0 to 6 mph	1500#	4' 0"	10' 0"	6' 0"	$ 3,340
No	250	0 to 6 mph	3750#	12' 0"	30' 0"	10' 7"	$25,000
No	125	2 to 4 mph	13,000#	10' 0"	34' 0"	8' 0"	$31,400
No	Not Available	3 to 4 mph	6900#	8' 0"	20' 0"	20' 0"	$ 9,897
No	50	2 to 3 mph	5000#	8' 6"	14' 4"	5' 0"	$ 7,600
No	30	> 5 mph	1350#	3' 4"	12' 0"	3' 6"	$ 1,625
No	45	0 to 8 mph	2800#	7' 0"	20' 6"	7' 7"	$ 6,082
No	>40	2 to 4 mph	2510#	6' 8"	14' 3"	8' 0"	$ 3,459
No	60	1 to 4 mph	4850#	8'-0"	15' 0"	5' 3"	$ 6,200



POTATO CHAIN SEPARATION MODE

FIGURE 3

blade to lift a layer of soil and rocks from the surface. Forward motion of the rock picker forces this material into the separation mechanism. The cutting depth is hydraulically variable on some models to permit adjustment while in operation. Soil conditions and operating speed affect the depth of penetration. In general, the deeper the cut the slower the rock picker must travel to avoid overloading the separating mechanism. The fixed blade pick up method is used on many models in conjunction with potato chain, rotating cage, or passive rake separation modes.

The rotating rake pick up method utilizes a rotating, spring loaded, combing reel and a grill type apron or blade to remove rocks from the soil. The revolving reel is a steel bar with hardened teeth which loosen the soil. As the reel rotates through the soil, rocks are forced up and over the grill and finally onto a conveyor or into a hopper. Soil is forced through the grill by the rotating reel and returns to the surface.

After the material passes over the digging head, it is deposited on the conveyor (potato chain). Most conveyors are heavy duty and made of steel mesh. Any soil remaining on the conveyor is sifted through before the rocks are deposited in a storage hopper. Though storage hoppers are more common, some models are available with discharge conveyors for direct truck loading.

Concealed large rocks or stumps can seriously damage these rock pickers, so most of the potato chain pickers are protected with an adjustable clutch or a shear pin in the drive line. Other models of this variety are protected by a heavy duty spring loaded digging head. With safety features such as these, serious downtime can be reduced.

Any agricultural tractor with sufficient horsepower and a PTO can operate this type of rock picker. Horsepower requirements vary from 50 to 250 hp depending on the size and depth of application. The PTO units are required to have 500 to 1000 rpm; again, this varies with the size of the rock picker. Hydraulics are necessary to control the digging depth and to empty the rear hopper.

Before the rock picker can be effective in farming applications, the land must be prepared. All stumps must be removed and the soil should be loose and dry. A disc harrow or chisel plow is recommended to loosen soil materials.

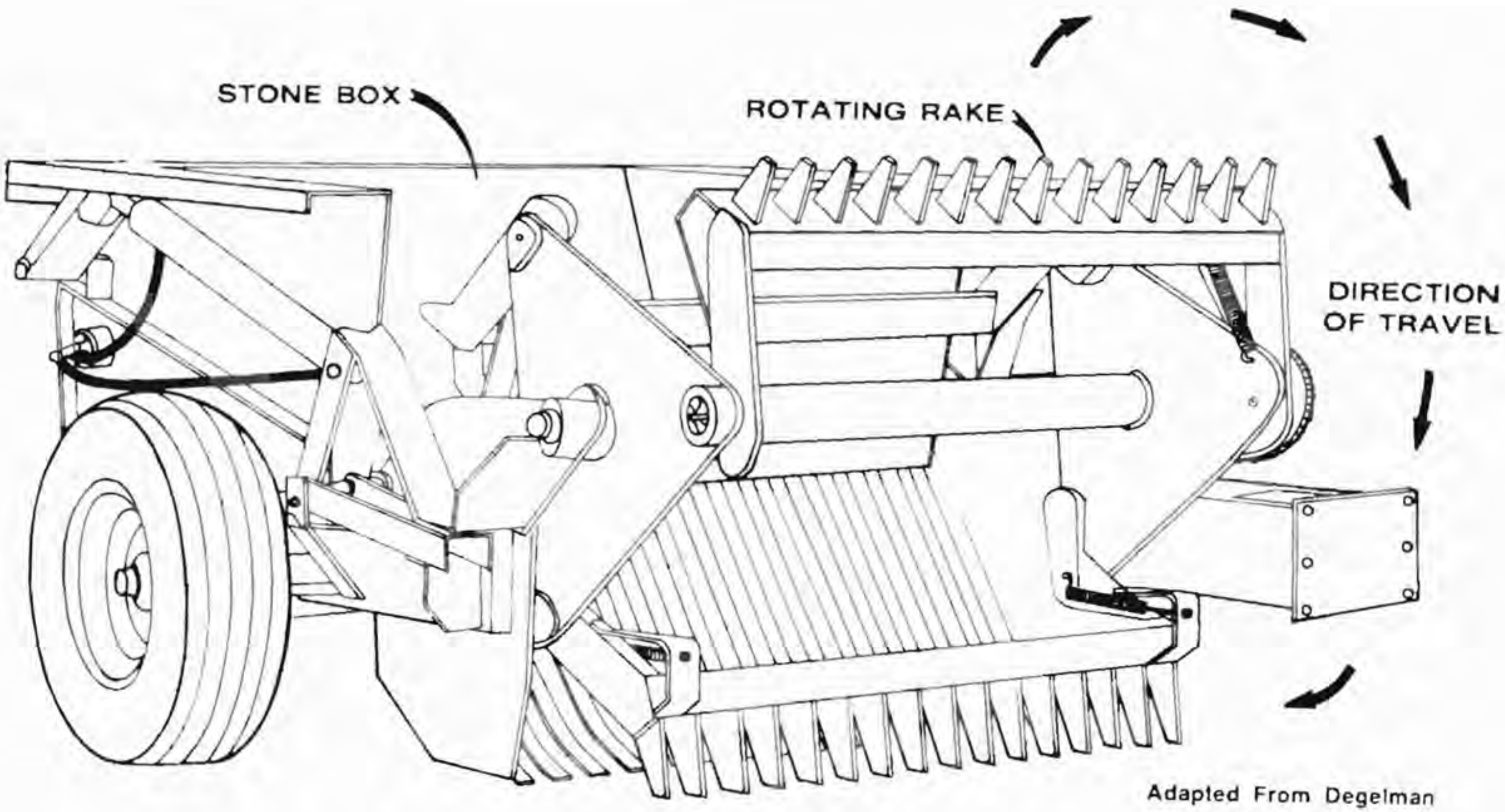
Production depends on three important factors: the type and condition of the soil, the amount of rock to be removed and the digging depth required. Since a wide variety of conditions affect production, manufacturers are reluctant to give any estimated production rates. Normally, a 3 or 4 inch layer of soil and stones is lifted onto the moving chain. As the chain vibrates, the soil mass is broken up causing the smaller particles to fall through the chain. However, if the soil load is too heavy or too moist, the chain does not vibrate and the soil particles are carried over the chain with the rock and deposited into the hopper. To eliminate this, the machine must be operated at a slower ground speed or at a shallower depth.

Double sieving of the soil is the major disadvantage of the potato chain. The returning chain travels under the separating chain and therefore, all the soil must pass through the two sections of chain. Some small stones or flat rocks pass through the upper chain, but do not pass immediately through the returning lower chain. These stones can jam the machine as they try to pass around the lower sprocket and roller with the chain. The results can be rapid chain wear or chain breakage.

Rotating Rake Rock Picker

The rotating rake is generally best suited to surface and shallow rock picking. The rocks must be loose and free or else the spring loaded rake teeth will ride over them. As the rake turns, it lifts rocks up onto a screen which allows the soil to drop out while the rock is directed into a collection box. These machines require dry, vegetation free soil since vegetation and damp soil bind the separation mechanism and make it inoperative.

Rotating rake rock pickers operate on the principle of a rotating, spring loaded picking reel passing over a heavy grill bar type apron (Figure 4). The depth at which the leading edge bar of the apron runs through the soil is controlled hydraulically, on most models, from the tractor. The action of the reel teeth loosens the rock, helps to break up clods, and rapidly moves the rock back into the hopper. Manufacturers claim that continuous picking operation even during tight turns is possible. They also claim a speed range from 1 to 5 mph, depending on soil conditions. Self cleaning action and very little jamming should be attained using rake rock pickers. The design of the aprons is generally such that, when used for surface work on pasture or sod, the machine will take all the surface rock with little tearing of the sod.



Adapted From Degelman
Product Literature

ROTATING RAKE SEPARATION MODE

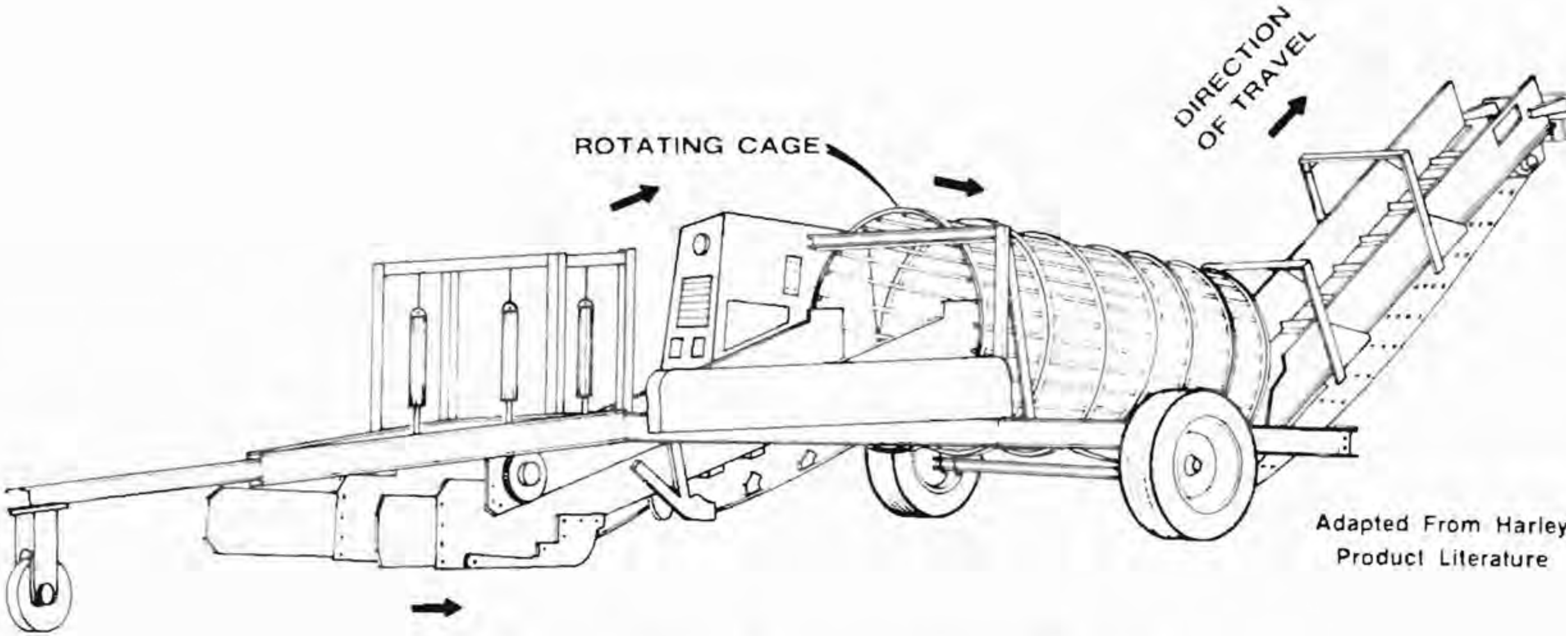
FIGURE 4

Again, the rotating rake rock pickers are towed behind an agri cultural tractor. Most of the models require a PTO, although some of the smaller, less expensive models are hydraulically driven. The major differ ence between a rotating rake and a potato chain rock picker is that the rotating rake forces rocks into the hopper, while the potato chain type utilizes a chain conveyor to transfer rocks to the hopper.

Rotating Cage Rock Picker

The rotating cage rock picker (Figure 5) does not penetrate the soil; rocks must be windrowed before this machine is employed. A rotating shaft pushes the rocks onto a conveyor belt that transfers them into the rotating cage. As the cage turns, tumbling rocks break up dirt clods, liberating soil particles that can fall through the cage openings and return to the ground. The inclined cage directs the rocks through the length of the cage to the rear conveyor, which deposits them into a storage hopper or following trucks.

For best performance by this type of rock picker, the rocks should not be mixed with excessive amounts of soil and vegetation. The separation area of this machine is the smallest of the four types. If plant material is encountered, it tends to clog the cage openings and reduce the available separation area even more.



ROTATING CAGE SEPARATION MODE

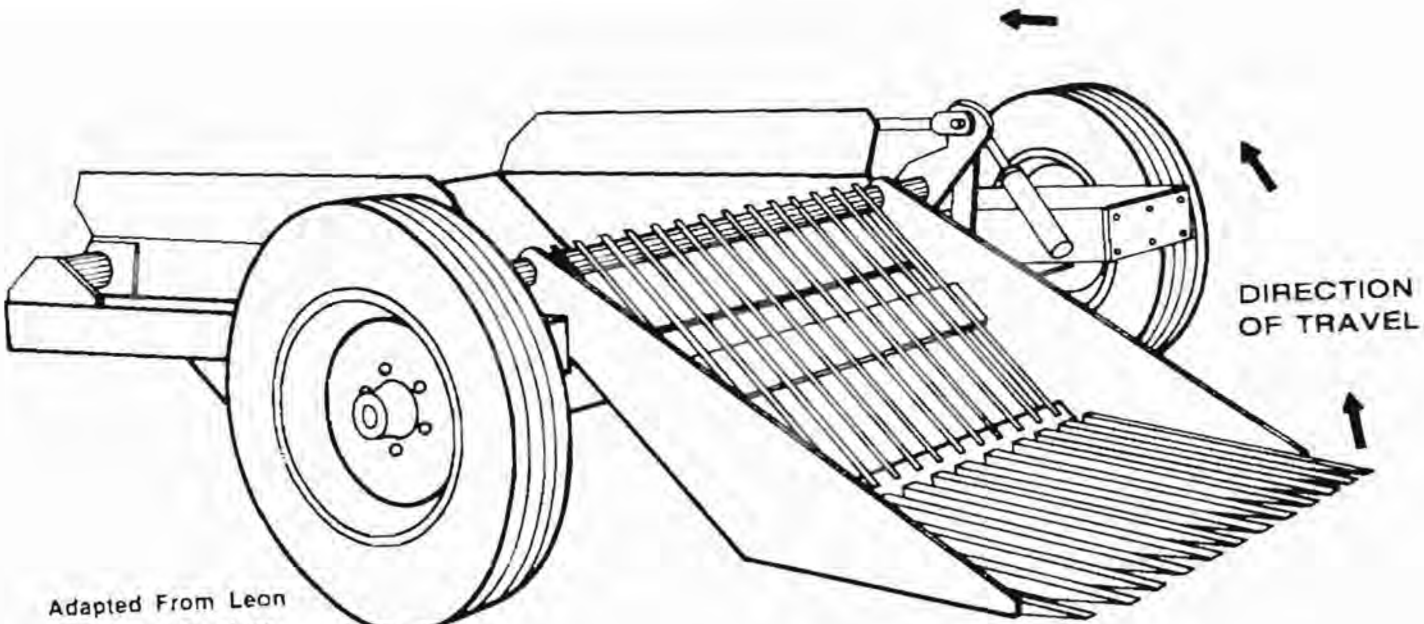
FIGURE 5

Rotating cage rock pickers are also towed behind an agricultural tractor and they are powered by a PTO and hydraulics. The overall length of these machines may cause turning problems in tight areas, since they are considerably longer than other rock pickers.

Passive Rake Rock Picker

Passive rake rock pickers (Figure 6) are the least complicated of all the available rock pickers. Most passive rake rock pickers have a fixed rake with adjustable tines. They are not designed to penetrate the soil more than a few inches. As the passive rake is towed behind a tractor, the rocks are maintained on the "L" shaped tines, while the fine particles fall through. When the tines are full of rocks, the collecting head is hydraulically lifted and dumped into the rear storage hopper. For effective operation, the soil must be loose and dry.

Passive rake rock pickers are pulled behind an agricultural tractor and only require hydraulic pressure for operation. Very little maintenance is required on these rock pickers, since only the spring steel tines come in contact with the soil. Horsepower requirements are minimal, due to their small size and shallow penetration. Most passive rakes have easily adjustable tines, which is one item most other rock pickers are not equipped with. Passive rake rock pickers should do well for light duty applications. However, wet, clayey soil conditions render them less effective than rock pickers that are equipped with rock/soil separation mechanisms.



Adapted From Leon
Product Literature

PASSIVE RAKE SEPARATION MODE

FIGURE 6

PHYSICAL LIMITATIONS OF ROCK PICKERS

This section includes a brief summary of some of the major capabilities and requirements of rock pickers listed in Table 3.

Penetration

Penetration depths stated by the rock picker manufacturers range from 0 to 12 inches. Several variables affect the penetration depth, such as operating speed, type of soil, weather conditions, and most important, the looseness of the soil. Before a rock picker can be used effectively, the soil must be broken up by other equipment (such as a disc harrow or a rock rake). Most rock picker manufacturers recommended that the soil be previously loosened and relatively dry before a rock picker is utilized. Since most mining companies do not have farm equipment, a rock rake attached to a dozer blade would be the most economical method to break up the soil.

Size of Rocks Picked

Rock sizes that can be handled by rock pickers vary considerably. A minimum rock size of 2 inches is recommended by most manufacturers, while the maximum rock size that could be handled varied from 10 to 44 inches. For the rock picker to handle a large size rock, it must be near the surface; otherwise, the rake bar will either force it deeper into the soil or just ride over it. Many of the rake bars are spring loaded to avoid breakage if a large rock is encountered. This safety feature is strongly recommended to minimize downtime for the equipment.

As the rocks are removed from the soil, they can be loaded into a hopper, or they can be windrowed. Most of the rock pickers listed in Table 3 utilize a hopper to temporarily store the rocks. After the hopper is filled to capacity, the rock picker is hauled to a disposal site and dumped. A few models are able to dump into a truck for faster haulage to the disposal area. Since dumping of the rock bin is a unproductive function, a further time-saving can be attained by conveying the rocks into following trucks. This method greatly reduces unproductive time, although it does require more operating expense. Using this conveyor method, more acres can be cleared more quickly than when hoppers are used.

Hopper Capacity

Hopper capacities ranged from a minimum of .75 cubic yards to a maximum of 8.0 cubic yards, although most of the rock pickers had a hopper capacity of 1.5 to 2.4 cubic yards. Assuming a rock picker has a penetration depth of 6 inches and the soil contained 1% rock, with a ground speed of 3 miles per hour, it would only take 3.2 minutes to fill a 2 cubic yards capacity hopper. Even though the above calculation is hypothetical, it clearly shows how quickly a hopper can be filled. Similarly, if the soil content was 20% rock, a 2 cubic yards capacity hopper would be filled in only 19 seconds.

Horsepower Requirements

Horsepower requirements for the towing tractor vary considerably among the rock pickers. The horsepower of currently available tractors ranges from 7 to 250. The majority of manufacturers recommend a tractor of about 50 horsepower to tow the machines. Since numerous variables affect horsepower requirements, it would be wise to be over powered rather than under-powered.

The majority of rock pickers use a Society of Automative Engineers category III power-take-off (PTO). The PTO is generally used to drive the rake bar and provide hydraulics for the hopper and other systems.

Operating Speeds

Rock picker manufacturers are rather reluctant to stipulate ranges of operating speed, since this greatly depends on site conditions. However, sufficient data has been obtained to indicate an operating speed range from 1/2 to 10 miles per hour. This is a significant range, although manufacturers stated that most owners operate their machines within the 2 to 4 miles per hour range.

When rock conditions are severe, operators may make more than one pass; the first pass at a slower speed, and later passes at increased speed. Most operators can visually determine how effective the rock picker is working, and can adjust their ground speed accordingly.

Slope Limits

The steepness of slope affects all earth moving equipment, including rock pickers. Generally, rock pickers are employed in flat lying or gently rolling prime farmland regions, where the slope is not a problem. However, when rock pickers are used on steep slopes, the maximum degree of slope in most cases will be determined by the tractor towing the rock picker. The slope will affect the rotating cage and potato chain rock pickers more than the passive rake type, since the rotating cage and potato chain conveyor are set at angles for optimum performance.

When steep slopes are encountered, rock pickers can still be effectively utilized. Some of the manufacturers have optional flotational tires which can assist the rock picker on steep slopes.

Slopes in excess of 30% pose severe limitations for farm tractors and would; therefore, hinder the use of rock pickers. However, removal of rocks from sloped surfaces will amplify the erosive effects of surface water runoff and may be more detrimental than the rock prevalence. Thus, it can be said that rock pickers can operate wherever it is practical to remove rocks.

Machine Weight

The weight of rock pickers, even when fully loaded, will not present any compaction problems during reclamation. The heaviest rock picker (13,000 pounds) uses large rubber tires to minimize ground pressure.

Depending on the size of the rock pickers, weights ranged from 1,350 pounds to 13,000 pounds. Even if hopper capacities were substantially increased, the overall weight would not affect compaction such that revegetation would be reduced.

Length and Width

The most important of these dimensions is length. This dimension can affect the turning radius of equipment. In restricted space areas, shorter models may prove more desirable than the longer equipment.

The width on many of the machines has been restricted to 8 feet. This restriction on the width enables the machines to be transported via flatbed trailers without special permits.

ROCK RAKES

Another form of rock removal device is the rock rake. Table 4 lists the general specifications of some popular models. Rock rakes can either be dragged behind a tractor or pushed by a dozer. The dragged varieties are used for light duty application and will not penetrate the surface. Dragged rakes only windrow surface rock and debris. Other methods must be used to pick up the windrowed material.

The push type rock rakes are attached to the front of a dozer. They can be effectively used to remove large rocks and vegetation from the soil. Again, since the rocks are not picked up, they must be pushed into a pile or burial pit. The tines on the rake are generally about 12 inches

TABLE 4

ROCK RAKE SPECIFICATION COMPARISON TABLE

COMPANY	MODEL	HORSE POWER REQUIRED	OPERATING SPEED (mph)	TINE SPACING (inches)	PENETRATION (inches)	WEIGHT (lbs.)	HEIGHT	WIDTH	PRICE (1979 FOB Factory)
DRAG TYPE									
Austin Products Inc.	Little [illegible]	55 H.P.	0 - 6	2	Dragged On Top Of Earth	370	3'-4"	8'-0"	$ 825
Brillion Iron Works	LR-6	30 H.P.	0 - 5	2	"	455	4'-6"	8'-0"	$ 654
Degelman Industries Ltd.	Rock Rake & Brush [illegible]	50 HP	3 - 5	2	"	3200	3'-8"	14'-0"	$ 4,860
York Modern Corporation	R.E.	25 H.P.	2 - 6	2	"	425	3'-2"	8'-0"	$ 1,550
PUSH TYPE									
Fleco Corporation	9-S	Use With D-9 Dozer	Varies With Equipment	12	21	10,520	5'-4"	13'-8"	$18,100
Rockland	FF-3 for Fiat-Allis	Use With Fiat-Allis Dozer	"	12	20	5,800	5'-8"	11'-6"	$ 8,710
Rockland	RF-3 for Cat	For D-9H Dozer	"	11	20	7,500	5'-11"	11'-11"	$ 8,710

apart and can penetrate the surface up to 21 inches. Push type rock rakes are most often employed for clearing and grubbing operations. They can assist rock pickers by removing large rocks and loosening the soil.

CRITLRIA USED TO SELECT ROCK REMOVAL EQUIPMENT

Selecting rock removal equipment is dependent on soil conditions, size of rocks, whether rocks are on the surface or buried, and amount of rocks present in the soil. Tables 3 and 4 can assist in selecting the most suitable machine for specific needs.

For applications where most of the rocks are on the surface, any of the smaller models will perform satisfactorily, since they are primarily de signed for surface rock. Some of the smaller models, and all of the rotating cage variety require that rocks be windrowed before the rock picker can be utilized. Auxiliary rake equipment may be necessary when selecting this type of rock removal equipment.

The hopper capacity is the one variable which must be carefully selected. For an efficient operation, there are three prime factors which dictate the size of the hopper: Distance the rock picker must travel to dispose of rocks, the percent of rocks in the soil, and the desired depth of rock-free soil. As these factors increase, the hopper capacity should also increase accordingly. Of the three, the distance traveled to dump the rocks is most sensitive, and should be kept to a minimum at all times for an economical operation.

When the percent of rock and the depth of rock free soil increase, a larger rock picker is recommended. The hopper capacity is also critical on these larger and more complex machines. Furthermore, even though some manufacturers claim their machines can achieve up to 12 inches of penetration, they also highly recommend that the soil be relatively dry and previously loosened by other methods. Rock pickers are not designed like scrapers, and, if they are used in wet or compacted soil, efficiency is reduced and mechanical failures will surely result.

OPERATIONAL ANALYSIS OF SELECTED CASE HISTORY MINES

OPERATIONAL ANALYSIS OF SELECTED CASE HISTORY MINES

In order to assess the cost and practicality of implementing rock removal techniques in present day mining schemes, the study processes outlined in this segment of the report were persued. First, all operations at two of the mines visited, titled here Case History Mines #8 and #9, were mapped, organized and costed through a discounted cash flow analysis. In addition, topsoil recovery and reclamation costs of the other seven (7) visited mines were assessed and are presented in Appendix A.

With the above mine costs available, a sensitivity analysis was prepared to determine the impact of rock removal processes on the scenario mines. Costs developed for the scenario mines have been projected to the other seven operations studied.

Case History Mine #8 is a typical midwestern area mine in a prime farm region. Topography and soil conditions are well suited for implementation of a rock picker into the reclamation plan.

Since the economics of introducing a rock picker will vary with the mine type, size and soil rock content, a smaller mine providing a more difficult application was chosen for Case History Mine #9. Case History Mine #9 affects 30 acres per year, versus 190 acres for Case History Mine #8, and is a contour mine located in the Cahaba coalfield of Alabama. The surrounding countryside is typically hilly, forested and rocky terrain.

CASE HISTORY MINE #8

Case History Mine #8, illustrated in Figure 7, is a typical midwestern area mine in a prime farm region, which produces 1,350,000 tons of coal per year. The topography is characteristically flat to gently rolling cropland. Climatic conditions for this area range from 42°F to 60°F annual mean temperatures with total precipitation varying from 36-50 inches yearly.

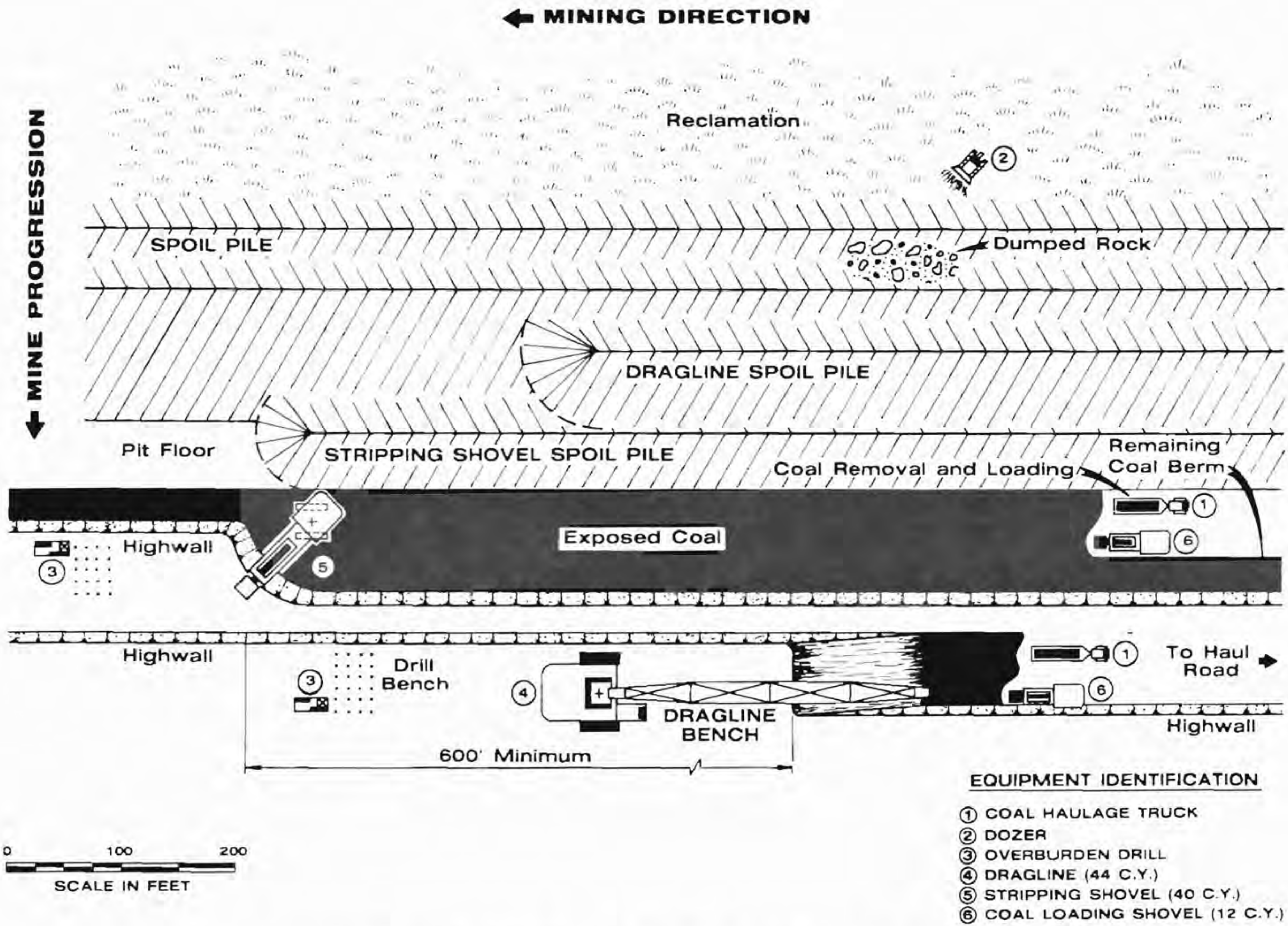
Coal seam thicknesses total 48 inches for the Herrin (No. 6) coal and Harrisburg (No. 5) coal; these seams are flat lying with less than a 2 degree dip in any direction. Overburden analysis indicates 30 feet of unconsolidated material, 3-4 feet of sandstone above the #6 seam and 25 feet of sandstone and shale between the #6 and #5 coal seams. Topsoil is an average of 4 feet thick with the A Horizon being 18 inches and the B and C Horizons of 18 inches and 12 inches, respectively.

Unit Operations

Topsoil Removal

Topsoil removal begins with the preparation of 3 stockpile areas according to the following:

- The A Horizon is removed from the first strikeline cut area with a 31 cubic yard scraper and is stored separately on an A Horizon stockpile.
- The B and C stockpile area is cleared of the A Horizon in preparation for storing the B and C subsoil.



MINING SEQUENCE - CASE HISTORY MINE NO. 8

FIGURE 7

- The D Horizon from the first strikeline cut must be stockpiled separately, until the mine progression has reached its last cut, and the D subsoil can be replaced. The D stockpile area must be cleared and the A, B, and C soil removed and stored in their respective areas.

Since it is impossible to begin reclamation until the mine has advanced a minimum of 3 complete strikeline cuts, the topsoil for the additional two strikeline cuts is also stored. Reclamation begins after 3 cuts and topsoil is directly replaced on the spoil area from this point on.

Drilling and Blasting

Drilling is accomplished in two eight hour shifts per day using a truck mounted 10 3/4 inch drill which averages 17 holes per shift. A drill hole pattern of 21' x 24' is used, and blast holes average 70 feet in depth. The blasting agent used is ANFO. Loading of 600 lbs. per hole causes the overlying strata to be sufficiently fractured and provides easier digging for the dragline.

Overburden Handling

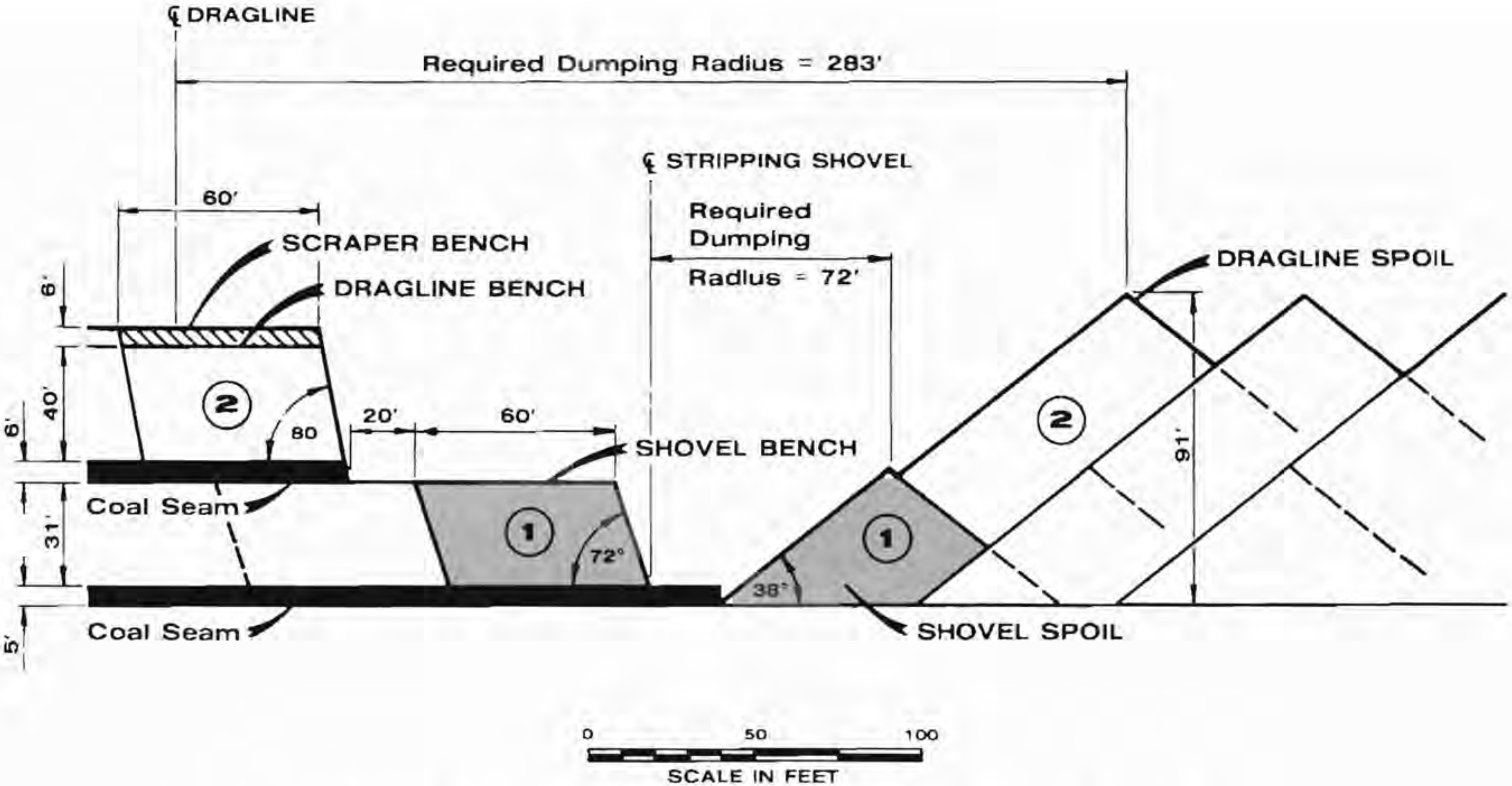
Overburden material is removed in two benches. The 31 foot lower bench employs a 40 cubic yard electric shovel excavating material and casting into its previous cut. Working ahead of the shovel, on the upper bench, is a 44 cubic yard dragline that removes 40 feet of the upper bench material casting it on top of the shovel's previous spoil. These operations are shown in cross section in Figure 8. When mining operations have reached the end of a cut, which is approximately 5,500 feet in length, both the shovel and dragline must deadhead and relocate at the beginning of the new cut. With adequate distance maintained between dragline and shovel, delays for relocating are almost nonexistent.

Coal Loading and Handling

Coal loading and haulage is conducted on a daily basis utilizing two 12 cubic yard coal loading shovels working the upper and lower bench. This operation remains a minimum of 100 feet behind the dragline operation. Initially, the coal seam is loosened by one of the reclamation dozers, equipped with a ripper. Each 12 cubic yard shovel loads company owned 100 ton coal haulers for the two mile round trip to the tipple.

Reclamation and Topsoil Replacement

Regrading operations commence with the completion of the third cut. Reclamation dozers begin by capping the spoil pile and burying large rocks and boulders. Dozers scarify the surface by blackblading in preparation for the replacement of the B and C subsoil by scrapers. From this point on, the replacement of the A Horizon and the B and C Horizons proceeds immediately as a continuous operation of direct removal and replacement in the regraded backfill area. At the end of mining, the final cut is filled with the stored initial cut material and topsoil from the stockpiled area. Seeding is also conducted concurrently with the advancement of the mine. Using a



CROSS SECTION - CASE HISTORY MINE NO. 8

FIGURE 8

hydroseeder and tractor, a mixture of tall fescue, pasture grasses and fertilizer is applied to establish growth and regenerate soil conditions before the planting of row crops.

CASE HISTORY MINE #9

Case History Mine #9, illustrated in Figure 9, is located in the Cahaba coalfields of Alabama at the beginning of the Appalachians, where it produces approximately 147,000 tons annually. Topography at this site ranges from rolling to moderately steep hills. Pre-mining land use is mainly forested with sporadic farming throughout. Climatic conditions are influenced by the Great Plains weather and rainfall ranges between 56 and 64 inches per year, with severe hail storms during the winter months. Mean minimum temperature is about 45°F with mean maximum at 80°F, with 0°F readings for short periods of time.

Coal seam thickness of the No. 6 seam (Herrin) totals 36 inches and it is assumed to be flat lying. Overburden consists of 20 feet of unconsolidated material and 60 feet of shale and sandstone above the No. 6 seam. Case History Mine #9 is a conventional contour stripping operation that uses a 9 cubic yard dragline and scrapers assisted by bulldozers. A 7 cubic yard front-end loader loads coal into contracted coal haulers for delivery to a coal broker.

Unit Operations

Clearing and Grubbing

Vegetative cover at this 30 acre site consists of small diameter hard woods with very little of marketable value. Clearing is accomplished by dozers knocking down trees, removing stumps, and piling material at pre determined sites for burning. The clearing and grubbing operation is kept well ahead of the mining operation.

Topsoil Removal

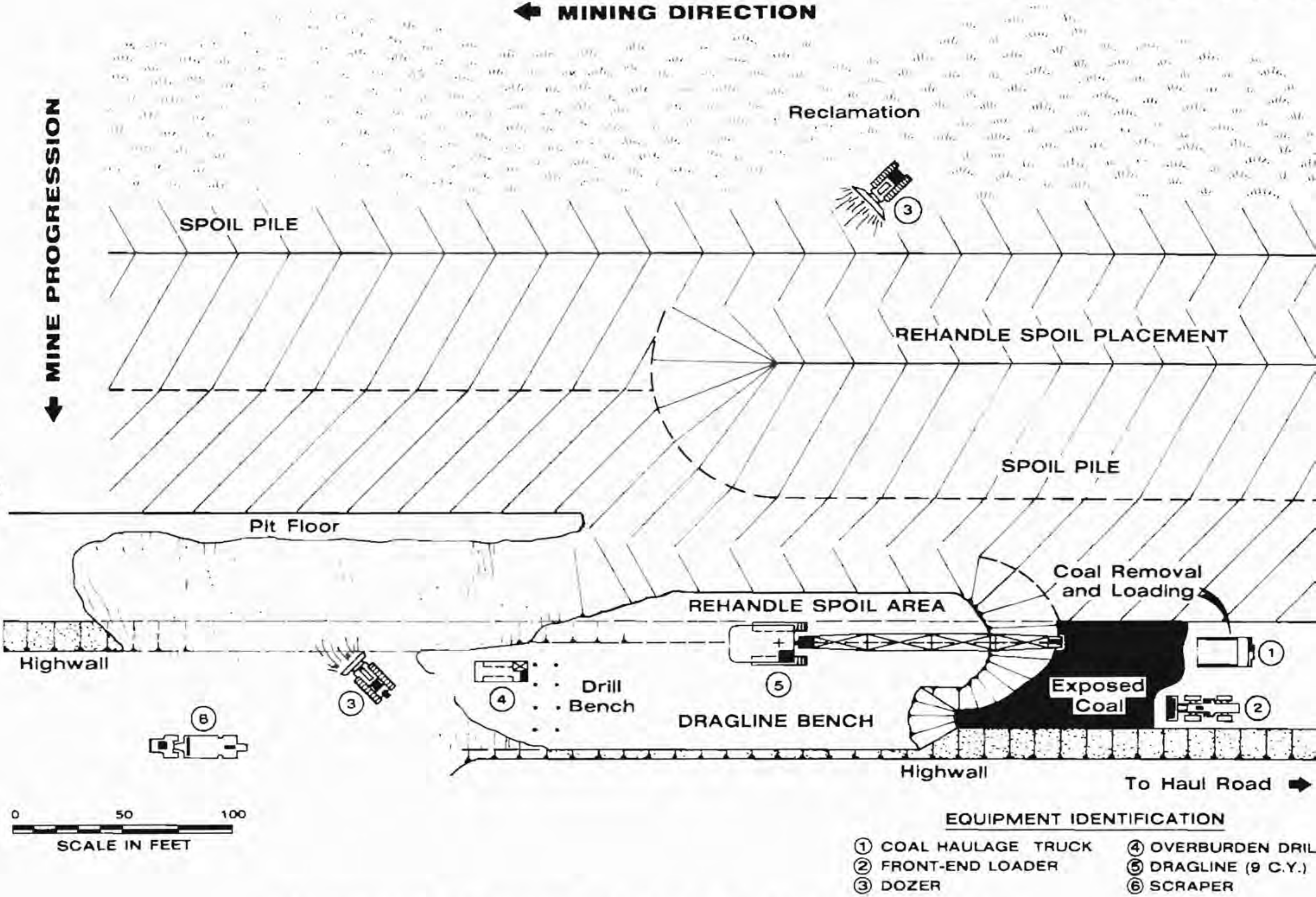
Topsoil removal methods for this site are essentially the same as described in site one. Scrapers and dozers remove 12 inches of topsoil and stockpile it at various locations for easier replacement. With the limited amount of this material, there is no need for segregation.

Drilling and Blasting

This mine uses a 6½ inch diameter air rotary blast hole drill for holes on 12 foot centers. The entire 80 feet of overburden is blasted to facilitate easier removal by the scrapers and dragline. Drilling schedules for this site require two 10 hour shifts per day, 345 days per year.

Overburden Handling

Primary stripping units for overburden removal are a 9 cubic yard dragline and a 30 cubic yard push-pull scraper. During the initial cuts, the upper 20 feet of overburden is removed with a scraper and stored until there is sufficient advancement in the backstack area to allow direct removal and replacement. The lower 60 feet of overburden above the coal is removed with the 9 cubic yard dragline utilizing the extended bench method of removal. Due to the dragline's insufficient boom length for correct spoil placement, it



MINING SEQUENCE - CASE HISTORY MINE NO. 9

FIGURE 9

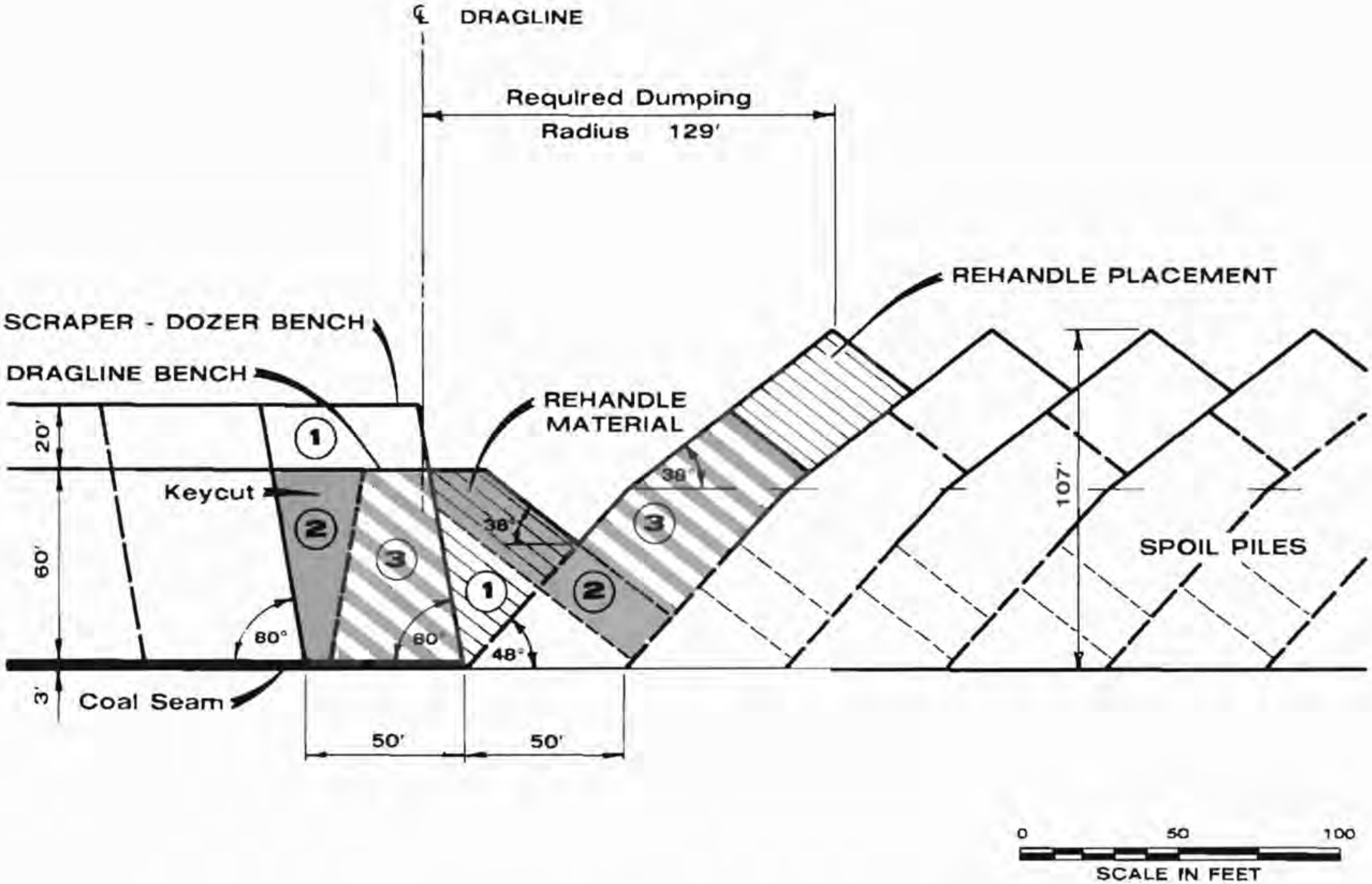
must rehandle approximately 27 percent of its material to create the extended bench. This will allow the dragline to achieve the proper distance, and material angle of repose necessary to prevent spoil roll back. This operation is scheduled two 10 hour shifts per day, 345 days per year. Scraper scheduling required to maintain an adequate distance in advance of the dragline is one 10 hour shift per day, 345 days per year. These operations are shown in cross section in Figure 10.

Coal Removal and Loading

Coal loading and haulage is conducted on an as-needed basis. A dozer cleans and rips the coal for the 7 cubic yard front-end loader to load 25 ton contracted coal haulers to be transported to a coal broker for processing before being sold on the open market.

Reclamation and Topsoil Replacement

The sequence of this operation is very similar to that described in Case History Mine #8. Spoil piles are graded before the replacement of the scraper overburden and then regraded and scarified before topsoil replacement. The final cut is filled with the initial cut and the excess scraper material that was previously stored. Reseeding and fertilizing is through the use of a hydroseeder and tractor.



CROSS SECTION - CASE HISTORY MINE NO. 9

FIGURE 10

SENSITIVITY ANALYSIS

SENSITIVITY ANALYSIS

Introduction

There are several methods available for evaluating the unknowns involved in investment decisions. The sensitivity analysis approach is one way in which to quantitatively incorporate risk and uncertainty into analyses.

This approach refers to an assessment of the relative magnitude of the change in one particular element resulting from varying another element over a wide range of values. If no drastic change results, the situation is said not to be sensitive to uncertainties regarding that varied element. On the other hand, if a small change in the estimate of one element will drastically affect the desired result, the situation is said to be very sensitive to changes in the estimates of that element.

Some typical parameters that often are allowed to vary for sensitivity analysis include initial investment, selling price, operating cost, project life and salvage value. In this study, the sensitivity analysis was performed on the topsoil removal and reclamation efforts per acre.

Variable Parameter Descriptions

In order to determine the affects of implementing a rock picker into the reclamation plans, a sensitivity analysis was performed. While keeping certain criteria constant and varying those items which would most likely fluctuate, sensitivity graphs were constructed. Criteria held constant throughout this analysis were:

1. 6 inch effective penetration depth of rock picker
2. 8 foot effective picking width
3. 5 mph ground speed during dumping cycle
4. 60 second dump cycle
5. $30,000 cost for rock picker and tractor
6. 7½ hour shifts
7. UMW operator for tractor (Grade 1)
8. 90% availability of rock picker and tractor

Items considered as variable were:

1. Operating speed-varying from 1 to 5 mph
2. Hopper capacity-varying from 4 to 16 cubic yards
3. Haul distance to dump-varying from 0 to 5000 feet
4. Hopper versus direct loading

Each of the four variable items above was graphed as a function of the percent of rock contained in the topsoil. These analyses of the relationship between the rock content of the topsoil and the horsepower required to remove that rock (expressed in horsepower-hours/acre) provide a visual display of the sensitivity of the reclamation effort to these variables. The graphs in Figures 11-18 were plotted for each variable, the percent of rock on the horizontal axis (varied from 5-20%), and the corresponding horsepower-hours/acre value on the vertical axis.

Horsepower-hour/acre units were chosen to portray the incremental increases in the rock removal effort as the rock content increased in order to provide a relationship of universal and timeless application. These units reveal the physical energy required to accomplish given tasks by summing the products of the total available potential flywheel horsepower outputs of all contributing pieces of equipment multiplied times the total hours over which they were applied. This figure is, in turn, divided by the number of acres reclaimed. These units can be converted to cost/acre in a single step, at any future point in time, by simply multiplying times a conversion factor.

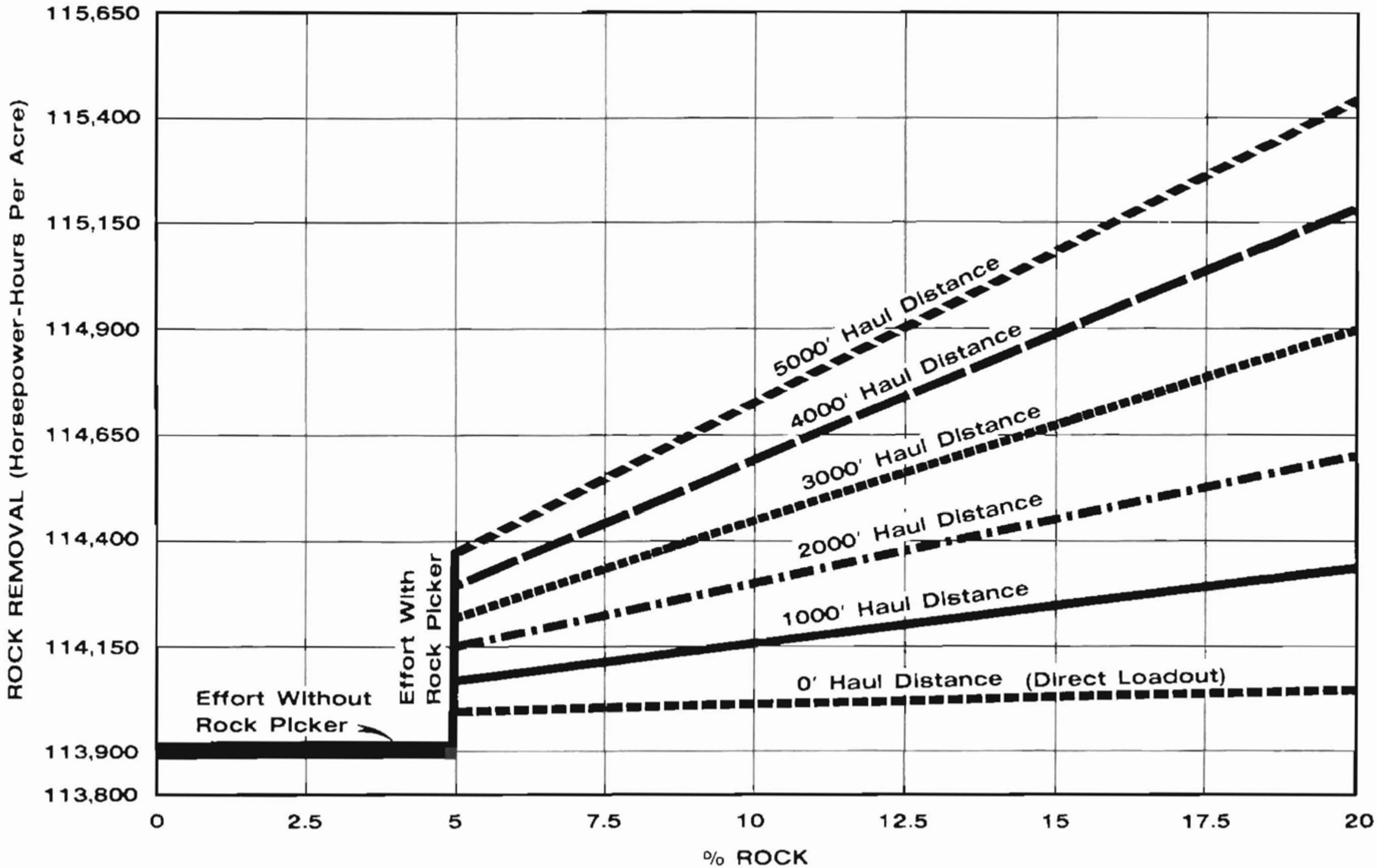
Each graph shows the effort required to remove the topsoil rocks to a depth of six inches using a direct acting rock picker. Each graph begins at a rock content of 5%, since removal of rock is not anticipated below such a nominal value.

The basic assumptions for determining the rock picker's cycle time were a 1 mph operating speed, 4 cubic yard hopper capacity, 5,000 foot average haul distance, and hopper loading (instead of direct loading into trucks).

Varying Haul Distance

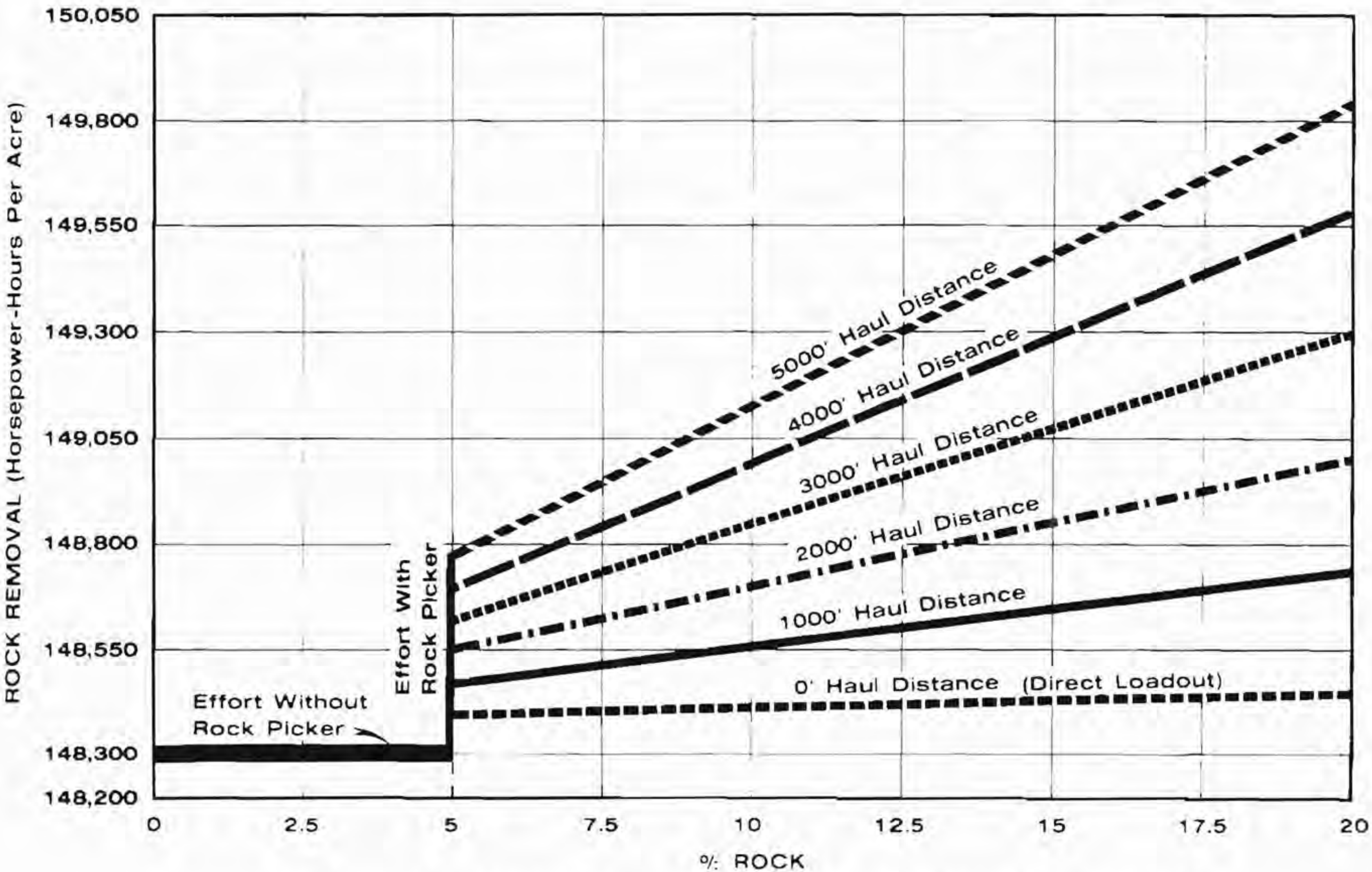
Figures 11 and 12 reveal that as the haul distance increases from 0 to 5000 feet and the percent of rock increases from 5 to 20%, the horsepower-hours expended per acre also increase. This is a directly proportional relationship. The increase in expended energy is caused by the increasing cycle time. As the percent of rock content increases, the number of times the dumping cycle must take place is increased. Also, cycle times increase as haul distances increase, resulting in lower production rates.

From Figure 11 it can be seen that at a 7% rock content and a 4000 foot haul distance, the effort required was calculated to be approximately 148,900 horsepower hours per acre. The percent of difference between this new effort and the effort without a rock picker is 0.40%, which is a very minor change. The percent of difference between the maximum rock removal



CASE HISTORY MINE #8 - RECLAMATION EFFORT/ ACRE VS % ROCK (Varrying Haul Distance)

FIGURE 11



CASE HISTORY MINE #9 - RECLAMATION EFFORT/ ACRE VS % ROCK (Varying Haul Distance)

FIGURE 12

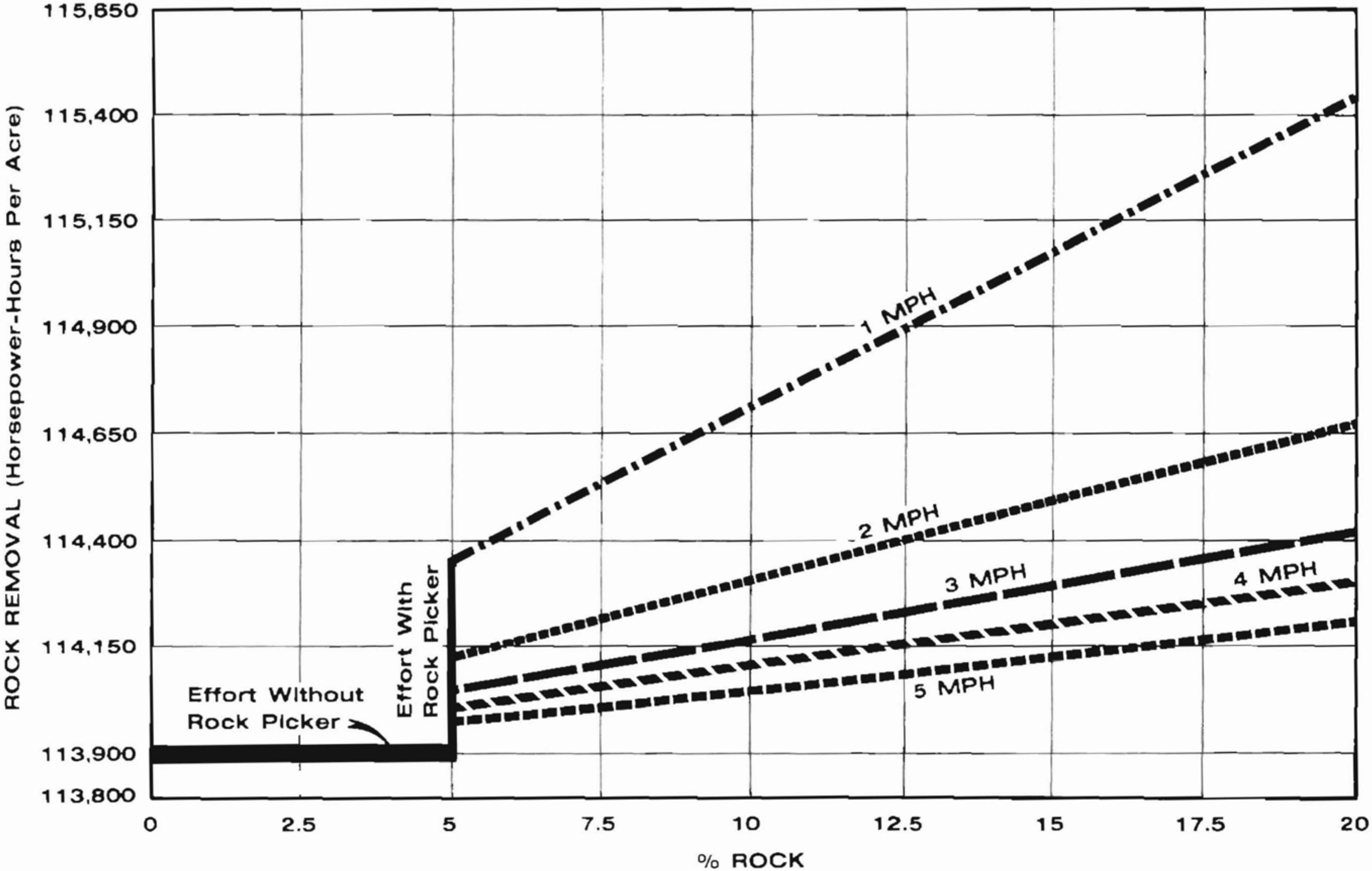
effort of 149,800 horsepower-hours/acre for 20% rock content and the effort without a rock picker is 1.0%, while Figure 12 shows a 1.3% difference. Both of these changes are minimal and the relationships can be considered to be very insensitive.

Also, as the haulage distances decrease, higher rock content has less of an effect on productivity, due to the faster cycle times. This end result is the reason for the slopes of the lines being flatter as the haul distances decrease.

Varying Operating Speed

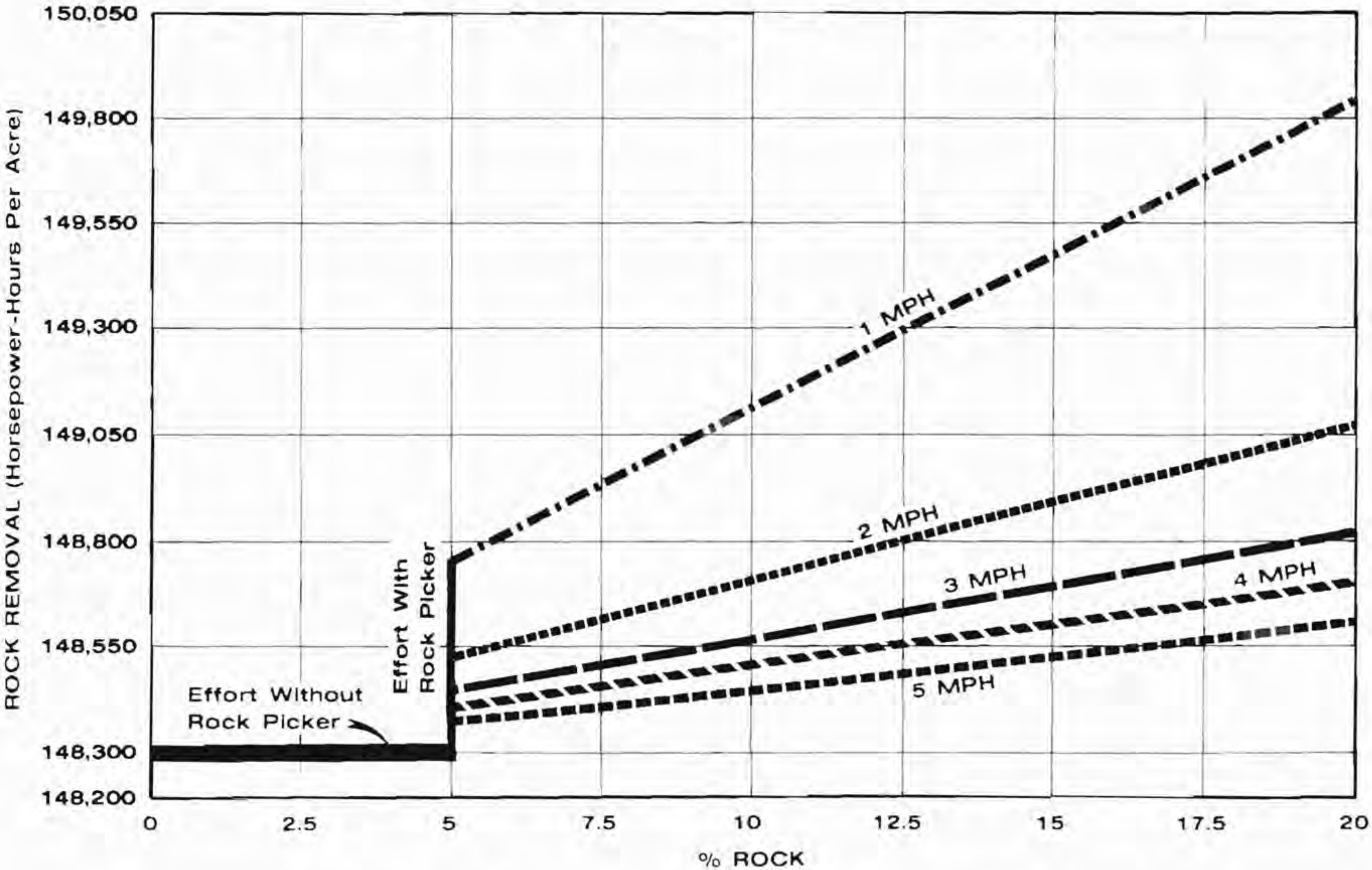
The graphs presented in Figures 13 and 14 illustrate the relationship of operating speed, percent rock, and effort per acre for reclamation and topsoil removal. Picking speeds vary from 1 to 5 mph and, again, rock content ranges from 5 to 20%. This effort to speed relationship is inversely proportional in that, as the speed is increased, the effort expended decreased. This results from higher speeds causing shorter cycle times and consequential higher productivity. The percent of rock to effort relationship is directly proportional for reasons explained in the previous section.

From Figure 13, it can be seen that for a 10% rock content and a picking speed of 3 mph, topsoil removal and reclamation efforts will expend 148,575 horsepower hours per acre. The percent of change here is only 0.19%. Overall, the percents of change in Figures 13 and 14 are the same as in the previous section, again, revealing a highly insensitive situation.



CASE HISTORY MINE #8 - RECLAMATION EFFORT/ ACRE VS % ROCK (Varying Operating Speed)

FIGURE 13



CASE HISTORY MINE #9 - RECLAMATION EFFORT/ ACRE VS % ROCK (Varying Operating Speed)

FIGURE 14

Varying Hopper Capacity

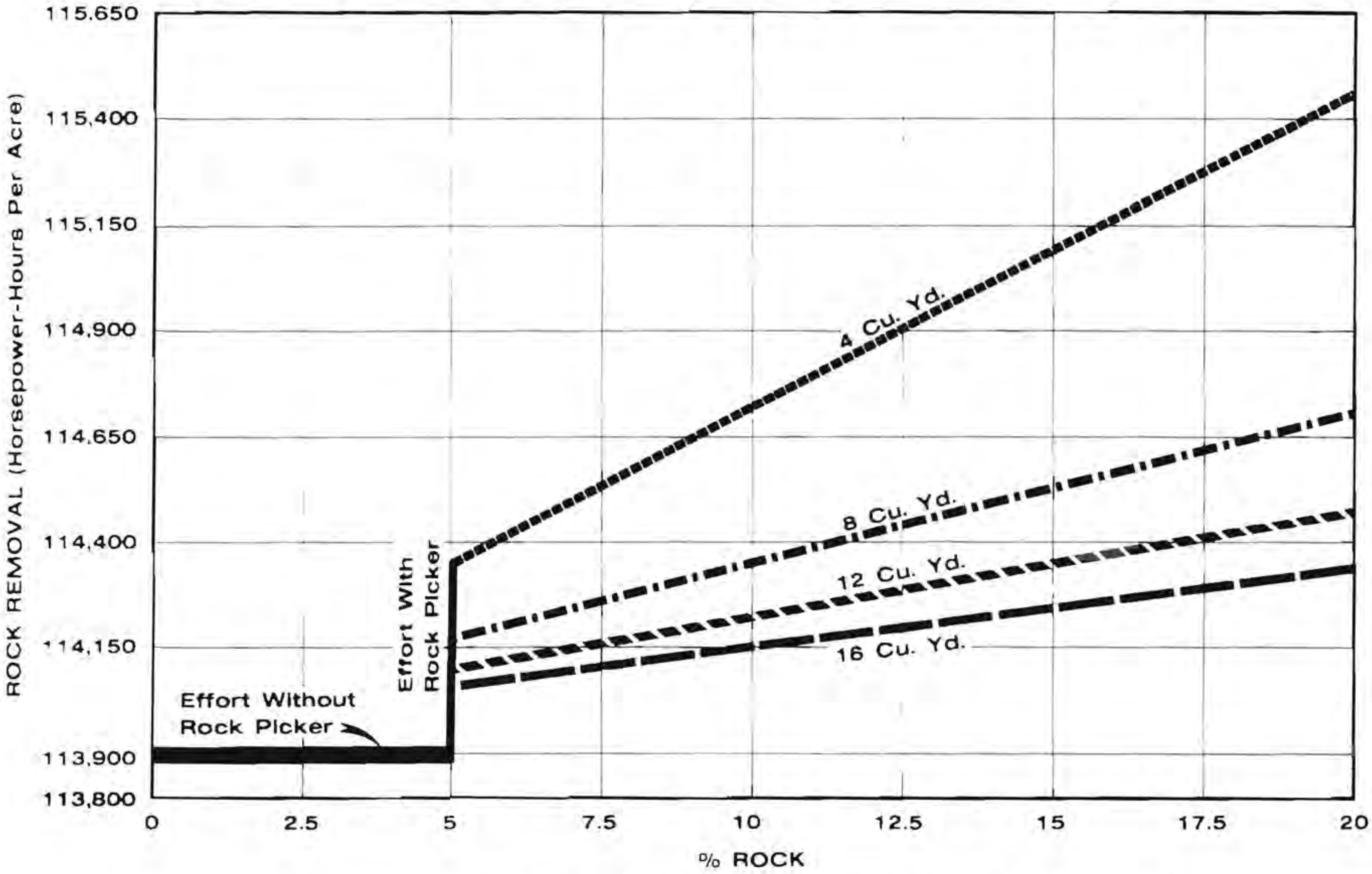
Different hopper sizes on the rock picker will definitely affect production, for obvious reasons. Larger hopper capacities result in higher productivity. Cycle times are essentially the same using large or small hoppers, however, more material is transported with larger ones, resulting in higher productivity. Figures 15 and 16 are graphs depicting the results of varying the hopper capacity from 4 to 16 cubic yards. Another inversely proportional relationship is exemplified here in that, as hopper capacity increases, the effort expended per acre decreases, due to the increased productivity. Again, as in the other sections, topsoil removal and reclama tion efforts per acre increase as the percent of rock increases.

Figure 15 shows a 1.0% difference between the highest rock picker effort and the reclamation effort without a rock picker. Figure 16 reveals a 1.3% difference. A highly incensitive situation is again revealed here as in the previous graphs.

The flattening slopes of the higher hopper capacity lines is due to the void ratios having less of an effect in the larger hoppers than in the smaller hoppers. The percent of void space would be less in a 16 cubic yard hopper than a straight line relationship would reveal.

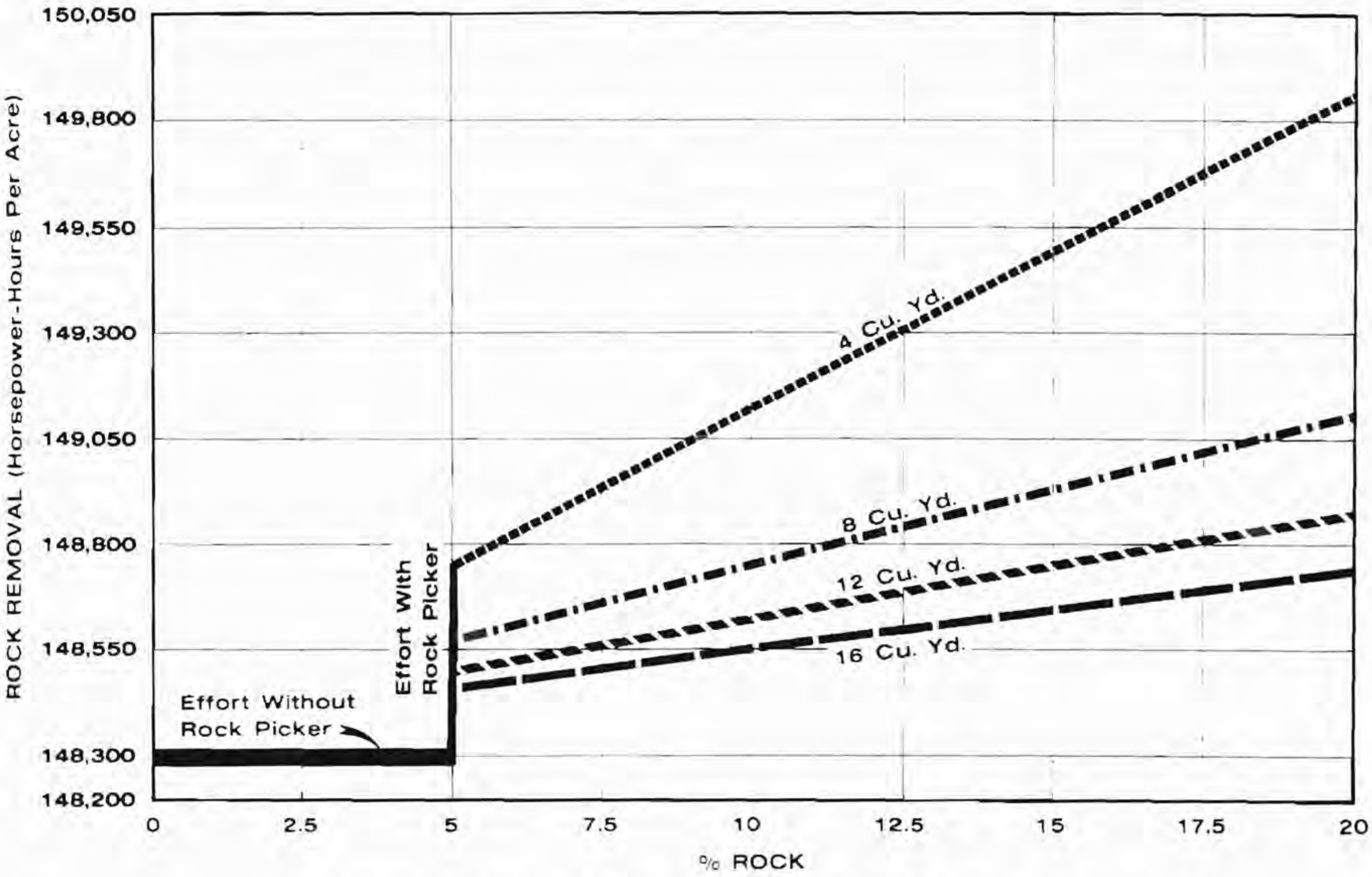
Hopper vs Direct Loading

The utilization of direct loading to trucks for material transportation (as opposed to hopper loading) reveals an increased effort expenditure due to the additional equipment required. This is illustrated in Figures 17



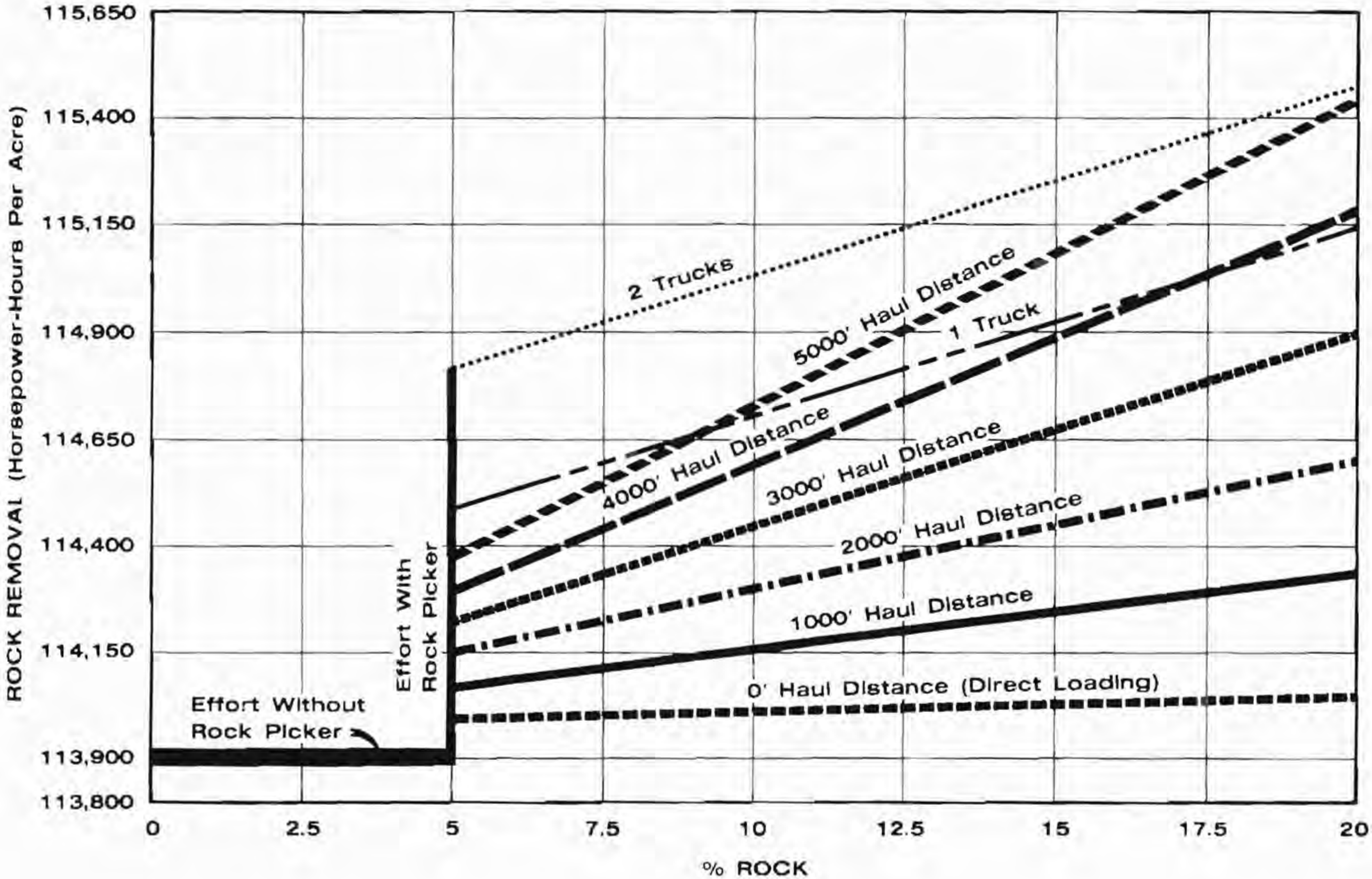
CASE HISTORY MINE #8 - RECLAMATION EFFORT/ ACRE VS % ROCK (Varying Hopper Capacity)

FIGURE 15



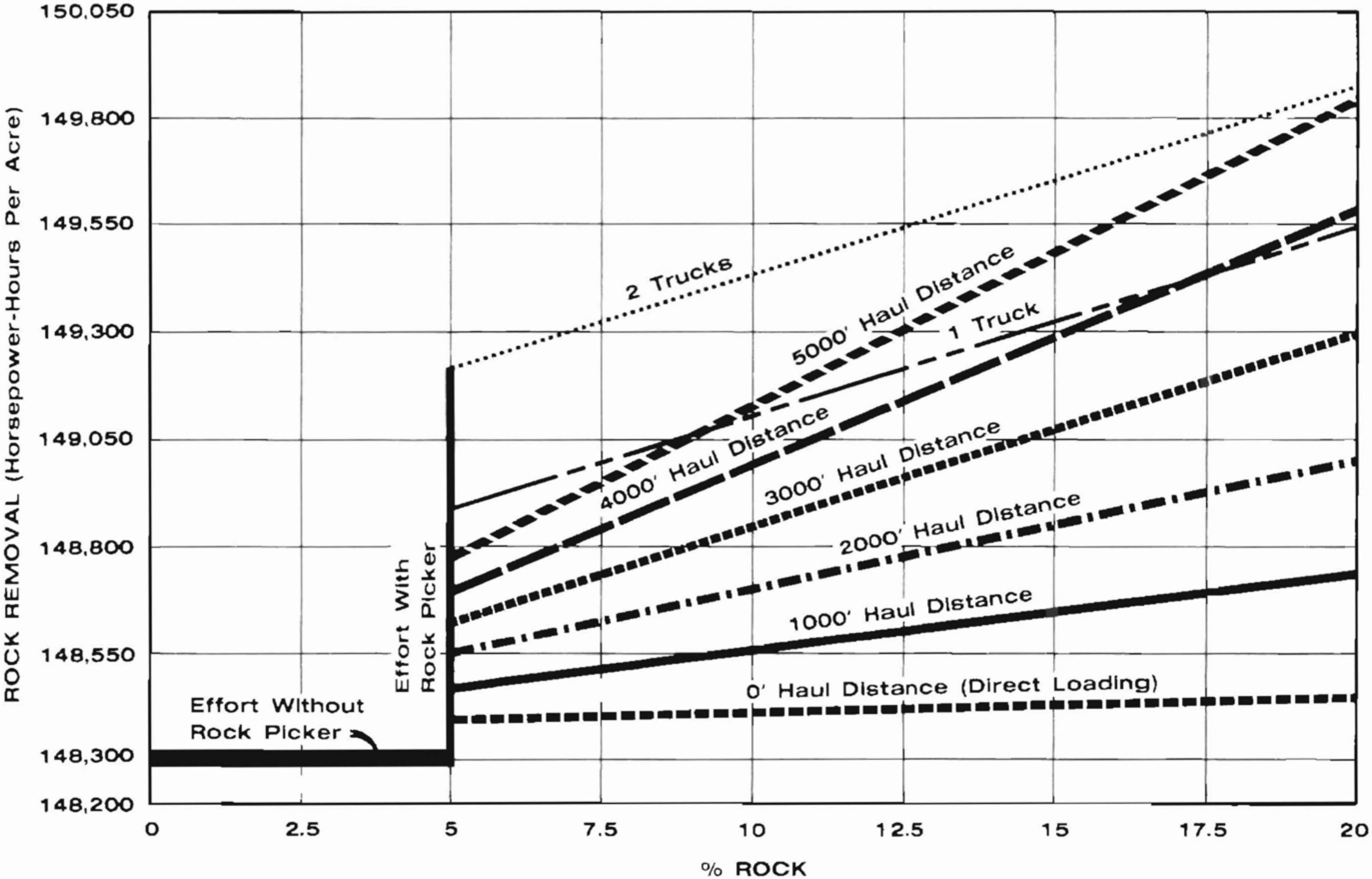
CASE HISTORY MINE #9 - RECLAMATION EFFORT/ ACRE VS % ROCK (Varying Hopper Capacity)

FIGURE 16



CASE HISTORY MINE #8 - RECLAMATION EFFORT/ ACRE VS % ROCK (Hopper vs Direct Loading)

FIGURE 17



CASE HISTORY MINE #9 - RECLAMATION EFFORT/ ACRE VS % ROCK (Hopper vs Direct Loading)

FIGURE 18

and 18. These figures show that employing a 350 horsepower truck is generally an excessive equipment deployment, since a truck is not helpful until the haul distance approaches a mile or the percent of rock becomes high. Yet even at these horsepower hour break even points one truck cannot keep up with the rate that a 4 cubic yard hopper will fill. If a second truck is added they can keep up with the rock picker, however, more of an effort must be expended than if the rock picker operated alone. Thus, in all instances (up to 20% rock content) direct loadout uses more effort than operating the rock picker alone.

When the rock content exceeds 20% and the haul distance approaches one mile, direct loadout can offer an effort reduction that will be effective.

Worst Case Analysis

When estimating the impact of additional or innovative equipment (or concepts) on the overall operation, sensitivity analysis reveals areas where adjustments could be made for estimating purposes, if the end result is highly sensitive with respect to that particular factor. Further investigation into evaluation could be accomplished by a worst case analysis. When conducting a worst case analysis, the objective is to define the most adverse set of circumstances that could feasibly be encountered during the unit operation.

The rock picker portion of the topsoil removal and reclamation effort for Case History Mines #8 and #9 was subjected to a worst case analysis to determine the net effect on the overall operating effort per ton. Factors selected to depict the worst case were a 1 mph operating speed, 4 cubic yard hopper capacity, 5000 foot haul distance, 20% rock content, and direct loading into trucks.

Applying these factors to Case History Mine #8's reclamation effort per ton of 16.0312 horsepower hours per ton compared with 15.030 horse power hours per ton without a rock picker, the difference is 0.0012 horse power hour per ton. Case History Mine #9 resulted in a 0.0107 horsepower-hour per ton increase or 0.035% difference (from 30.2588 to 30.2695 horse-power hour increase per ton).

As can be seen from the figures above, the incorporation of a rock picker into an operator's reclamation plan results in a minimal additional effort.

Required operating time is also low and readily sequenced into normal reclamation activities. By using a worst case situation (assuming: 1 mph picking speed, 20% rock content, 5 mph dump speed, 5000 feet to dump site, 8 foot swath, 4 cubic yard hopper and 6 inch penetration) it takes 8 hours to clear 1 acre of land. Assuming the same specifics, yet using a more realistic 10% rock content, will require only 3 hours per acre.

Some benefits to be realized would be improving the value of the land, increasing crop yield, improving aesthetics, and favorable public reaction to a company genuinely interested in improving post-mined lands and uses.

Projected Rock Picker Efforts

Table 5 presents the topsoil removal and reclamation efforts with projected rock picker effort for all nine mine sites visited. Unit efforts for topsoil removal and reclamation for the first seven sites are developed in Appendix A. Effort data obtained from the sensitivity analysis were used to compute the projected rock picker costs.

Also included in Table 5, are topsoil removal and reclamation efforts per ton of coal with and without the addition of a rock picker.

TABLE 5

TOPSOIL REMOVAL AND RECLAMATION EFFORTS WITH PROJECTED ROCK PICKER EFFORTS

MINE SITE	EFFORT WITHOUT ROCK PICKER		PROJECTED EFFORT WITH ROCK PICKER	
	H.P. - Hrs./Acre	H.P. - Hrs./Ton	H.P. - Hrs./Acre	H.P. - Hrs./Ton
CH-1	44,900	5.0652	46,462	5.0668
CH-2	72,700	15.9942	74,262	15.9958
CH-3	35,100	9.3535	36,662	9.3558
CH-4	123,100	11.3315	124,662	11.3363
CH-5	7,500	3.6608	9,062	3.6761
CH-6	217,100	15.5063	218,662	15.5175
CH-7	25,700	11.4131	27,262	11.4247
CH-8	113,900	16.0300	115,462	16.0312
CH-9	148,300	30.2588	149,862	30.2695
AVERAGE	87,600	13.1793	89,151	13.1860

ENVIRONMENTAL IMPACT

ENVIRONMENTAL IMPACT

Rocks are a natural component of soil; yet, at times they can be detrimental to revegetation efforts. Large rocks hinder attempts to seed an area. A prevalence of rock on or near the surface retards the establishment of vegetative cover by restricting root growth and limiting moisture distribution.

As a side effect of this impedence to vegetation, there will be an increase in the amount of sedimentation that occurs. Erosion, transportation, and deposition of soil particles impairs environmental quality. The source area is robbed of nutrient-providing soil, the transporting water becomes turbid and affects the aquatic life of the receiving stream, and the point of deposition can result in a clogged stream channel, lake, or pond, or in suffocation of productive land.

There can also be harmful effects on the wildlife from erosion and sedimentation in the form of destruction of their refuge areas. These are often damaged or destroyed without being noticed, since they are remote from the "affected area".

Past mining practices led to mixing of consolidated and unconsolidated strata within the same spoil pile. In the process, the strata were inverted, making it impossible to replace the topsoil in its original condition. In order to alleviate the destruction of the natural soil conditions, states began requiring separate handling of the topsoil. Those states which had no inherent rock problems in their topsoils required that post mining conditions shall be as rock free. Thus, the only stipulated rock content limitations in reclamation standards are those which reflect the natural soil conditions prior to mining.

Recently, implementation of the Federal surface mine law forced the segregation of soil horizons to be implemented nationwide. This practice has had a noticeable effect on those states without previous rock content restrictions. An extreme decrease in the contamination of topsoils by rocks is apparent. In essence, if an operator complies with the OSM regulations, the reclaimed areas should be of equal quality to their pre-mining conditions.

For the operator who plans to improve the land use from its pre mining status, the employment of a rock removal system is effective and relatively inexpensive. The economic impact on both the small and large operators is slight, as shown by the previous sensitivity graphs and unit cost estimates. In terms of the cost vs. benefit, any area whose land use has been improved will be more valuable than it was. The cost of utilizing a rock removal system that is properly sized for the volume of rock removal necessary can be more than offset by the increased land value.

In some areas, the degree of successful revegetation could be improved by using a rock removal system. This would be inexpensive insurance that an affected area will only need to be planted once to initiate successful revegetation. Such problem areas, where rock content hinders the success of a planting attempt, could be remedied by rock removal efforts.

Areas like the semiarid southwest, where topsoil is of limited quantity and poor quality and is underlain by decomposed sandstones, the probability of successful establishment of vegetative cover may be improved by special rock reduction methods. The productivity of a reclaimed area might be improved by employing a machine that resembles the "Triter", which was formerly marketed by the Heston Corp. The "Triter" is a rock picker which crushes the rock it engulfs and returns the reduced rock particles to the ground. It would seem that if this type of rock reduction was applied to the upper subsoil layers, it would increase the amount of soil material, improve the availability of soluble minerals for plant nutrients, increase the moisture retention capabilities of the root medium, and accelerate the development of soil horizons.

A possible disadvantage of using rock pickers in the reclamation of surface mines would occur when the removal of rocks accelerates the erosion of restored slopes. Removal of the resistance to erosion, which rocks provide, may allow excessive gullying to occur. This disadvantage of rock removal could be eliminated by frequent terraces, or contour plowing, raking, or discing. These practices retard surface flow velocities, reducing the water's erosive power.

Areas that are reclaimed for farming uses will experience the reoccurence of rocks periodically, due to the combined effects of repetitive plowing patterns, siltation, and frost action. Plowing overturns the topsoil and, if the same plowing pattern is repeated year after year, the result is a lateral shift of soil, which is most pronounced on sloping ground. Siltation can carry away thin layers of topsoils, which decreases the rock cover. Finally, frost action physically pushes rocks toward the surface. Separately these are minor factors, yet collectively they will allow rocks below the cleared level to migrate up into the tillage zone. This return of rocks will take varying amounts of time depending on the depth of rock removal and the depth of frost penetration. Overall, the infiltration of rocks into the tillage area is extremely slow and not a formidable problem; the current mining practices will provide a reoccurrence rate similar to the adjacent, unmined lands of similar strata.

NEW CONCEPTS TO IMPROVE TOPSOIL ROCK REMOVAL TECHNOLOGY

NEW CONCEPTS TO IMPROVE TOPSOIL ROCK REMOVAL TECHNOLOGY

During the course of these investigations, the soil rock content problem in agricultural areas was found to be less critical than originally anticipated. This is primarily true because current methods to remove stone and replace topsoils are reasonably effective in preventing significant rock contamination. Even at surface mines or in abandoned mined land areas where very little soil is available for cover material, the action of dozers leveling spoil and weathering tends to reduce top cover rock limiting the surface soil rock content to 40% or less. The need for improved rock removal technology beyond that presently available is not wide ranging and of immediate importance to the mining industry.

There are, however, some specific types of mining related problems that could be better solved with improved rock handling equipment. Abandoned mined lands may often have coarse, resistant rock materials on the surface. Present rock removal equipment would be hard pressed to renovate these kinds of lands efficiently if rock content exceeds 20%. Likewise, on mountain top removal sites where large, flat, farmable (but poor soil quality), expanses have been created, a more advanced rock removal system could produce a more productive land than would otherwise be possible.

The main requirement of systems employed to upgrade lands just described would be to make them larger and more rugged than current equipment. Several conceptual pieces of equipment follow. They include a modified scraper, rock picker with a hopper, a rock picker with direct loadout, a rock cutter, and an ultrasonic crusher.

MODIFIED SCRAPER

Figure 19 displays the modified scraper concept. Since scrapers are widely used for topsoil redistribution, this concept can eliminate rocks from being replaced with the topsoil. As the topsoil is being redeposited by the scraper, a vibrating steel grill will maintain rocks larger than 3 inches inside the scraper. After all the topsoil is discharged, the remaining rocks can be dumped in a predetermined burial pit. The vibrating steel grill can be raised up for dumping the rocks and for conventional soil pick up.

Since this concept is a modification to currently available equipment, development costs should be minimal. Also it could be utilized wherever scrapers are employed for topsoil redistribution. Relatively dry soil would be required for efficient operation. Its intended use is for soils containing a moderate amount of rocks. Since this concept rides on rubber tires, maximum slope limitation should be kept to less than 15%. The equipment will weigh approximately 96,000 lbs. and have about 330 horsepower.

Estimated development costs for this concept are in the range of $25,000 to $50,000 excluding the cost of the scraper. With successful implementation of this concept, rocks could be removed during topsoil redistribution, thus eliminating the need for other rock removal equipment. Estimated availability for this modified scraper should be 90%.

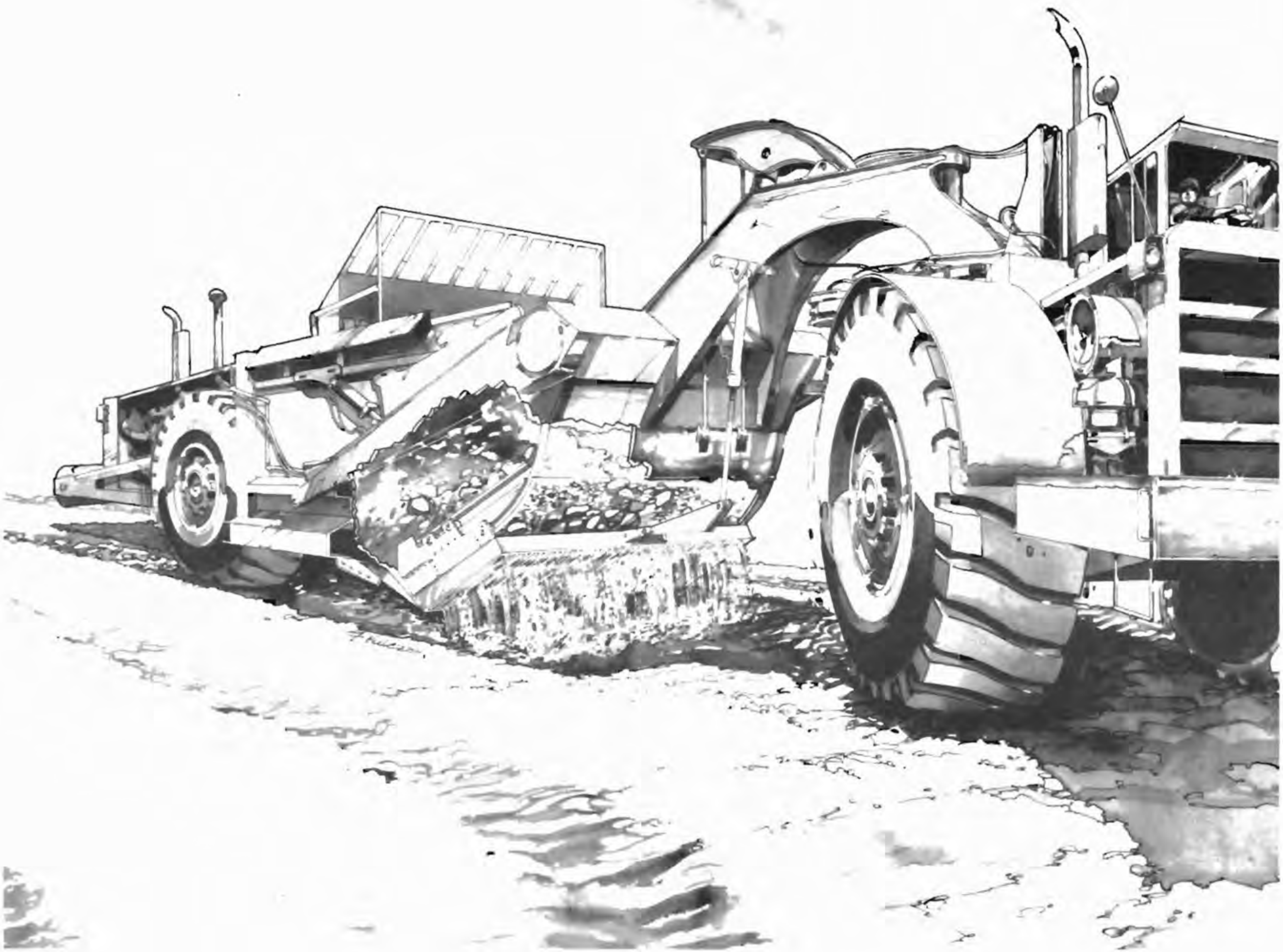


Figure 1[illegible] - Modified Scraper

ROCK PICKER WITH HOPPER

The rock picker with hopper storage concept (Figure 20) is basically the same as the rock picker with conveyor load out (Figure 21). The only difference between the two is that the discharge conveyor has been eliminated, and a hydraulically operated rock hopper is used to temporarily store the rocks. It is intended to be used for soils containing a minimum of rock, since using a conveyor discharge and following trucks would not be economical for this application.

The major components, (rock rake, pick up blade, agitating rollers and vibrating steel mesh conveyor) are the same as the conveyor discharge concept. With maximum slope set at 22%, 12 inches of soil penetration could still be maintained. The most important consideration in selecting a hopper type rock picker is the capacity of the rock storage hopper. Referring to Figures 15 and 16 quickly reveals that the overall operating cost is very sensitive to the volume of the hopper. An 8 cubic yard capacity should be sufficient for minimum rock conditions, but when percent rock increases beyond 15% careful consideration must be given in selecting the hopper size. The estimated costs for this concept are in the range of \$125,000 to \$175,000. The bulk of this cost will be absorbed by the dozer type chassis, with concept development taking 1-3 years for this 330 horsepower, 155,000 pound rock picker. Availability is anticipated to approximate 90%.

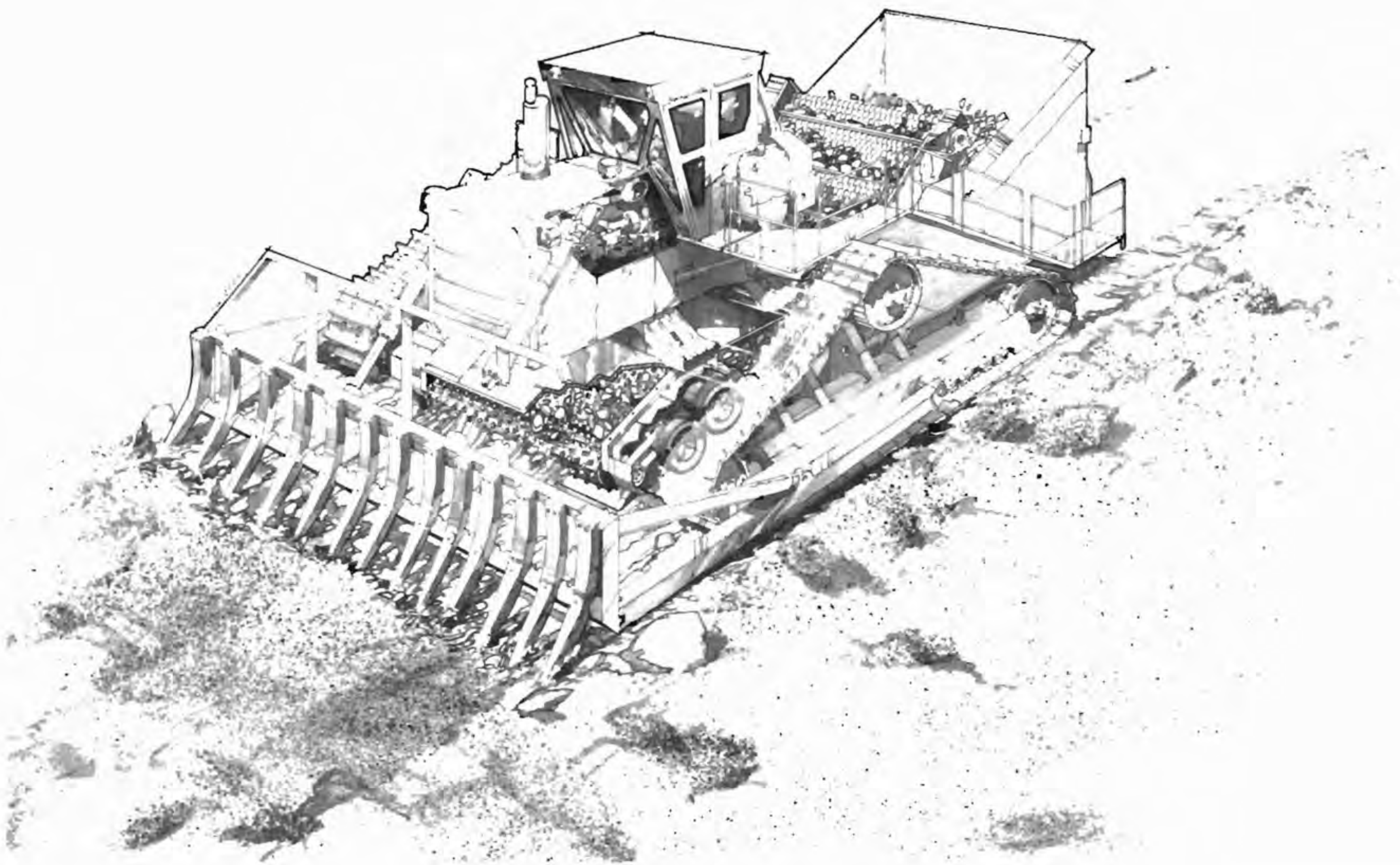


Figure 20 - Rock Picker With Hopper

ROCK PICKER WITH DIRECT LOADING

Figure 21 displays a combined new concept of rock removal. Using a modified dozer, a rock rake initially loosens the soil and pushes large rocks to one side. Next up to 12 inches of soil is picked up with an adjustable blade. A series of rollers breaks up the clods, moving the rock and soil to a conveyor. Using a meshed, vibrating steel conveyor, fine particles would fall through to the ground, while the rocks are conveyed to a storage hopper. The storage hopper, also equipped with a conveyor belt, would transport the rocks to following trucks. The 330 horsepower rock picker, weighing approximately 160,000 lbs., would ride on wide grouser type tracks to minimize ground pressure and reduce compaction, and increase its slope capability to a maximum limit of 20° to 22°. This concept could be used after topsoil redistribution for active mine reclamation or after clearing and grubbing in abandoned mined lands. Planting could follow directly afterwards, depending on weather and soil conditions, thus eliminating the need for plowing or discing. One or two rock trucks would be required depending on hopper capacity and percent rock in the soil.

This machine has potential for both surface mine and abandoned mined lands reclamation. Since this concept incorporates current technology into a new design, development costs would be minimal, implementation into the reclamation plan would be easy, and the benefits received could be substantial. Development of this concept will take 1-3 years. The estimated cost of this conceptual equipment is in the range of $150,000 to $200,000, with much of this cost for the purchase of a dozer type chassis. Estimated availability for this machine should be 90%.

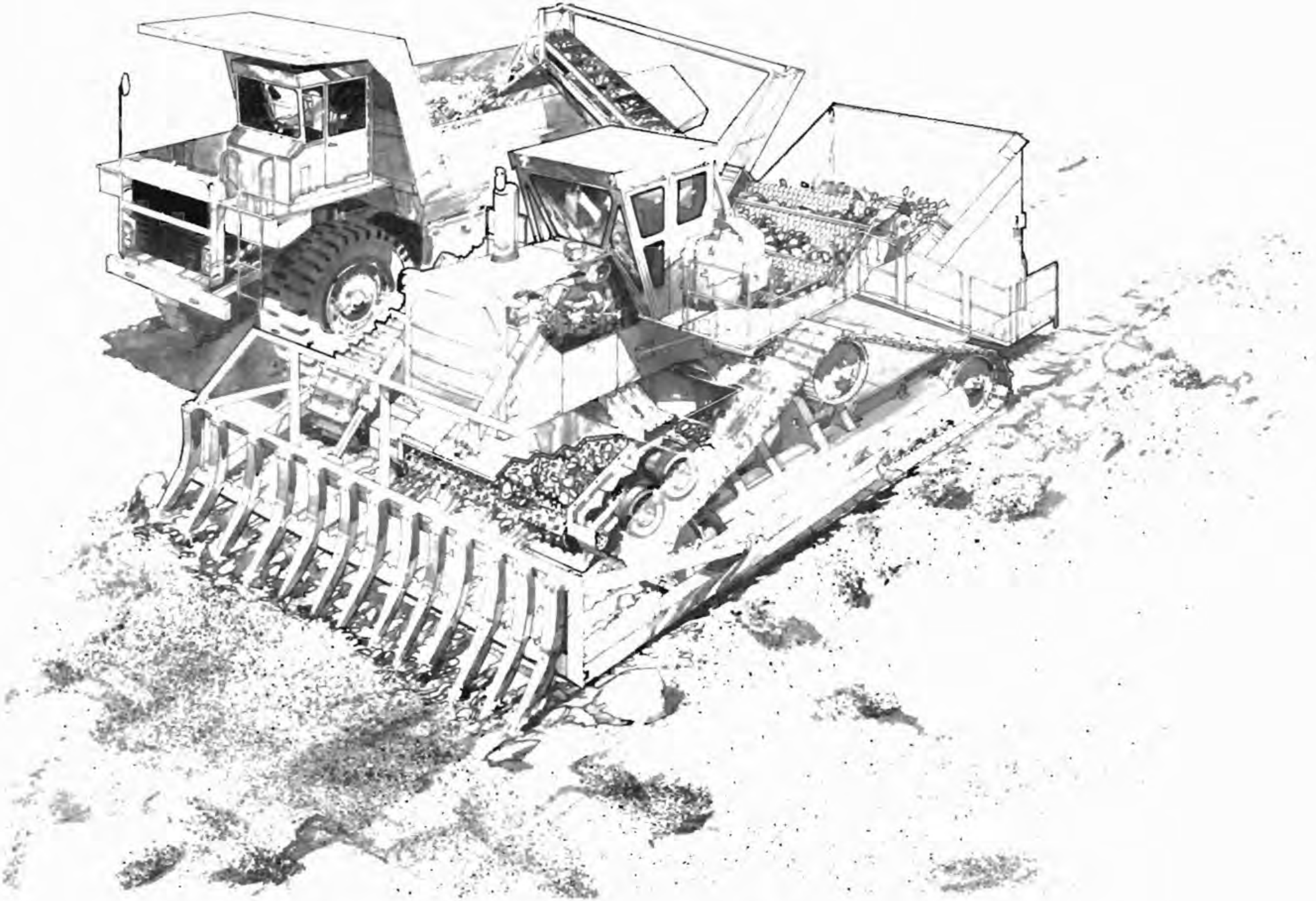


Figure 21 - Rock Picker With Direct Loading

ROCK PICKER WITH CRUSHER

The concept of selectively removing rocks from the soil, crushing them to a predetermined size, and redepositing the fines on the surface is presented by Figure 22. Pictorally, the storage hopper from the direct load out concept has been replaced with a jaw and roll crusher. The discharge conveyor has been moved to the rear of the machine so the fines can be spread evenly on the surface.

The main components of the concept are rock rake, an adjustable pick-up blade, agitating rollers, vibrating chain conveyor, primary jaw crusher, secondary roll crusher, and finally a discharge conveyor, all afixed to a dozer type chassis. Once the topsoil has been redistributed, the rock picker/crusher would first loosen the soil and expose large rocks with the rock rake. Material less than 12 inches would pass through the rake teeth and up to 12 inches of soil would be lifted from the surface by an adjustable blade. Agitating rollers would break up any lumps and move the material uniformly to a steel mesh vibrating conveyor. Material less than 1 inch in size would fall through the mesh and return to the surface, while rocks would be deposited into the primary jaw crusher. The rocks would be initially crushed down to 3 inches in size, and finally recrushed to 1 inch by the secondary roll crusher. After crushing, an articulated rear mounted conveyor would spread this material evenly over the surface.

Operating speed of the rock picker/crusher would have to be carefully matched to the output of the crushers. This system would eliminate the need for rock disposal, although a disc harrow would be required to

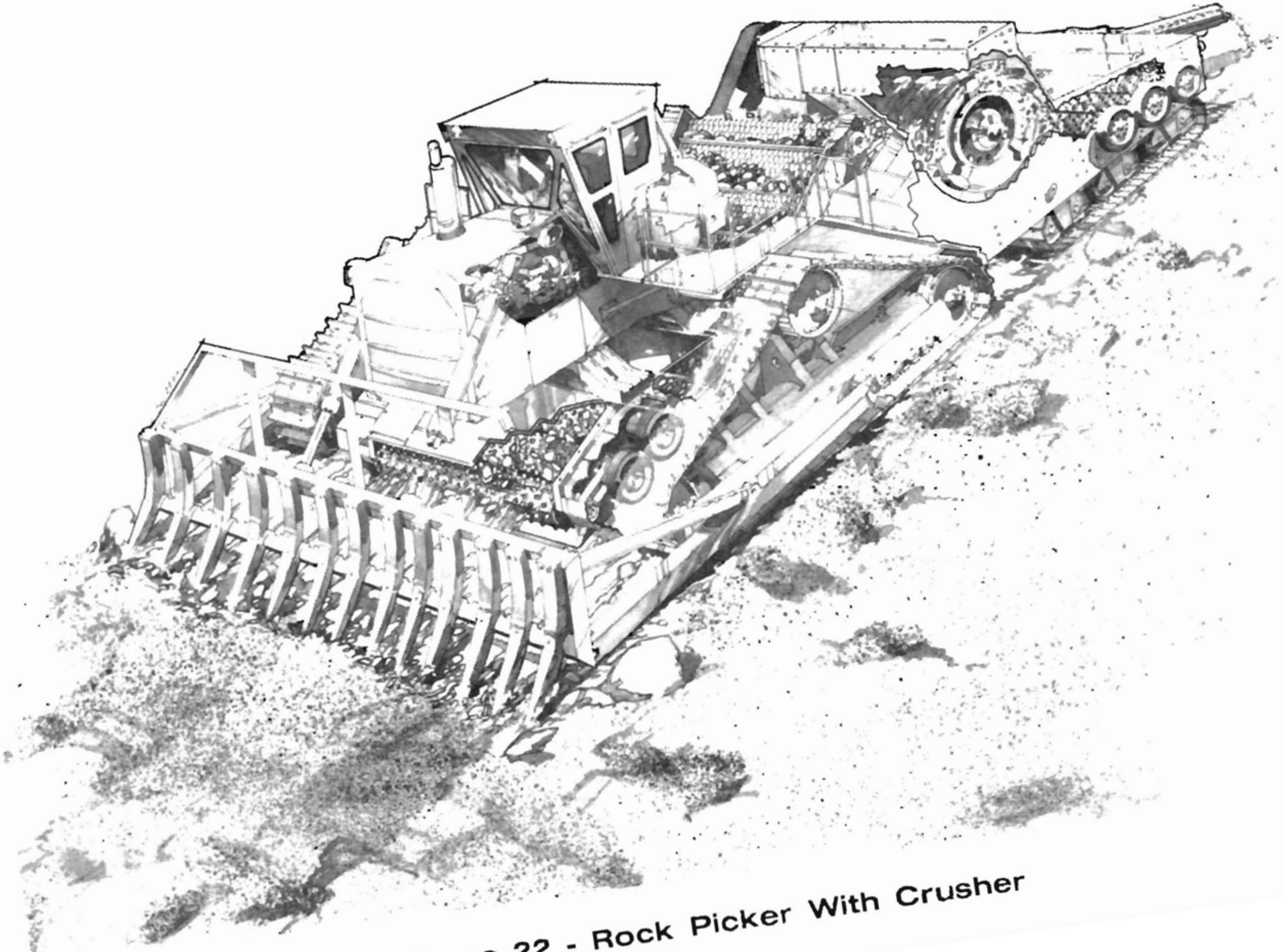


Figure 22 - Rock Picker With Crusher

mix the soil and crushed rocks prior to planting. Adapting the rock picker/ crusher components to a dozer type frame may prove difficult and costly, due to the physical size of the rock crushing equipment. The 230,000 pound, 400 horsepower rock picker/crusher would take about 3-5 years to develop. Using dozer tracks will enable the rock picker/crusher to negotiate slopes up to a miximum of 22%. The estimated costs for this concept would be from $250,000 to $350,000, with an estimated availability of 85%. The rock picker/ crusher would have more potential in moderately rocky soil conditions, and could also be used for abandoned mined lands reclamation.

ROCK CUTTER

The rock cutter concept (Figure 23) is a rather unique method to improve topsoil conditions. All other rock removal equipment must pick up a layer of soil (up to about 12 inches) in order to selectively separate rock from soil. However, the rock cutter concept, using a series of highspeed carbide cutters, will loosen, and cut rocks to 1 inch in size without lifting the soil from the surface.

The components for this conept include a modified dozer type frame, a rock rake to loosen the soil, three rows of cutters, and a protective shield to prevent any rock fragments from flying from the cutters. Three staggered rows of 27 inch diameter cutters will progressively reduce rock size to 1 inch. The oppositely rotating rows of cutters have been staggered to eliminate rocks from jamming between any two cutters. The depth and spacing of the cutters varies, so that rocks are reduced in size gradually. Operating speed will depend on the size and quantity of rock in the soil; however, speeds of 1

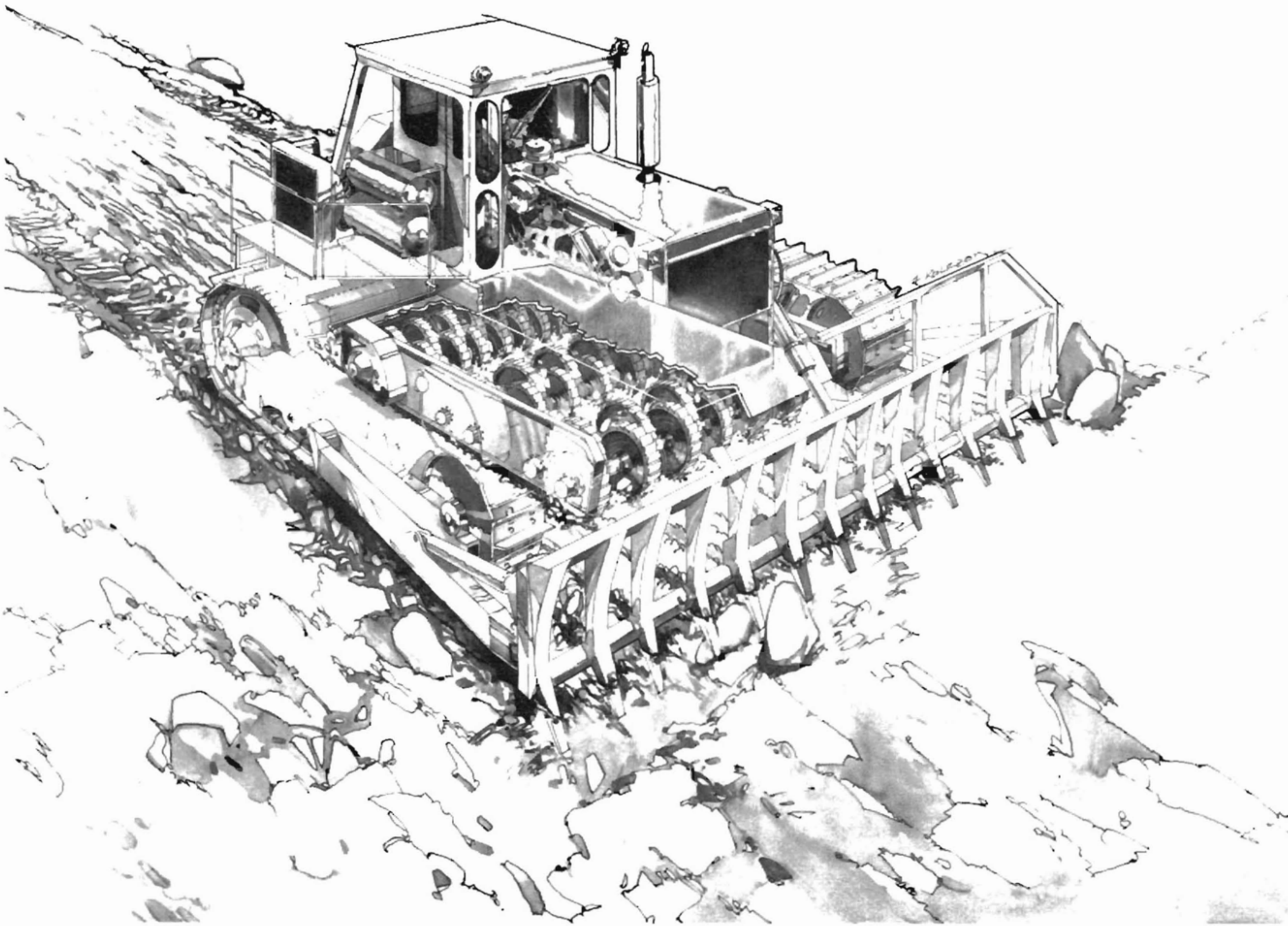


Figure 23 - Rock Cutter

to 5 mph are anticipated. Penetration capabilities for the rock cutter concept are set at 12 inches maximum depth and the wide grouser type tracks should enable the 190,000 lb. rock cutter to negotiate slopes up to 22%. Estimated availability should be 85% for this 400 horsepower machine. Development of this concept will take about 2-5 years.

Topsoil conditions will affect the amount of dust and noise caused by the high speed cutters. Maintaining sharp cutters will increase the effectiveness of this machine; and regularly scheduled maintenance is a must since large quantities of hard rock or sandstone will greatly reduce the life of the cutters. The estimated costs for the rock cutter concept are from $250,000 to $300,000. The rock cutter concept should have potential in severely rocky areas, and in abandoned mined lands where topsoil is limited. Adding the proper soil nutrients after utilizing this concept could well improve the soil conditions of thousands of acres of abandoned mined lands throughout the United States.

ULTRASONICS APPLIED TO ROCK CRUSHING

The field of ultrasonics is currently being explored to determine its usefulness in a couple of related applications that may provide trans ferable technology for rock removal practices. Ultrasonics (high pitched sounds above the audible range) is being used to propagate vibration which adds a mechanical advantage to cutting and ripping edges as well as crushing plates.

By applying vibration to a ripper tooth, subsoiler, or rock picker cutting edge could, according to current studies, increase the effectiveness of these implements. The vibration of a cutting tool appears to decrease the frictional resistence to penetration and would seem to have a primary separa tion affect of rocks from the soil containing it. This separation would result from the larger rock particles being pushed upward by the advancing tool while smaller soil particles would be sifted down into the subsequent voids.

There have also been experiments with vibratory activated crushers that were reported to have moderate success. Claims have been made that this type of crusher can reduce rock to powder in a single step, instead of the normal 2 or 3 stage crushing process. It is also purported that there is a significant reduction in the horsepower required by the sonic crusher compared to standard crushers as well as a decrease in the maintenance required. The sonic crusher is said to weigh only one-forth what a gyratory crusher weighs.

If these claims prove to be true it might be selectively used in combination with a rock picker to eliminate the disposal phase of rock removal. If such a crusher could be made portable, its implementation might be more feasible than completely revamping current rock pickers or mobilizing standard crushers. However, there are several physical complications to overcome before field employment can be attained. The vibration associated with traveling over rough ground must be isolated from interfering with the crusher's operational vibration. Secondly, the crusher must have an adequate feed rate to keep up with a rock picker and yet compact enough to be maneuverable. Finally, once the feed rate is adequate, the mass of the crusher must still be of portable size. Economically, its production cost may be excessive in order to overcome the physical complications and incorporate resonant drive bars of sufficient size and metalic quality. A major concern could be the need for high quality metal that could withstand the sustained vibration induced stresses.

CONCLUSIONS AND RECOMMENDATIONS

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The mandatory segregated removal, storage, and replacement of soil horizons during coal mining virtually eliminates the introduction of bedrock fragments into the reclaimed topsoil layer. This requirement is aimed at returning mined lands to their original state, thus the rock content should be unchanged. Rock removal importance to the mining industry lies in land beneficiation and reclaiming abandoned mined lands.

It is apparent that national implementation of rock pickers by the mining industry is neither necessary nor probable. However, for those instances when land use improvement is desired, a rock removal system may prove to be surprisingly cost effective.

Of the currently available designs, studies show that the direct acting rock pickers (Figures 3-5), those which continuously loosen and sieve a layer of soil, perform better and more efficiently than cyclic acting machines (Figure 6). Passive rakes often bounce off large rocks or force them deeper into the soil, making them less effective for rock removal. In addition, they are slower due to the required stops for emptying the rake into the storage hopper and for dumping the storage hopper. These two non-productive cycles of a 3 cycle operation greatly limit productivity rates as compared to the continuous direct acting types of rock pickers.

Land Beneficiation

Surface mine operators with a vested interest in the properties they mine could be shown that, for a nominal investment of capital and effort, a sizable valuation increase could be derived.

In areas where the former optimum land use was woodlands due to an inherently excessive rock content, this land could conceivably be up graded to grasslands. Likewise, in areas where cropland is scarce, a suitable substitute might be produced from previous grasslands or even wood lands.

The most impressive cost/benefit results, however, would be up grading rocky wasteland into a developable property. There are many minable areas with rocky or no topsoil and abundant bedrock outcrops. When these areas are mined, an increased amount of soil materials are produced. The incorporation of a rock picker to decrease its rock content would manufacture land of a quality that surpasses all its surroundings.

The financial advantage of a rock removal system begins even before the reclamation is completed on a severely rocky site. The removal of boulders and/or the reduction of the rock content can decrease the planting cost by permitting the mechanical preparation of a proper seed bed, mechanical tree planting and improved revegetation success. Thus, the initial cost of planting as well as the probability of partial or total replanting (to meet the bond release requirements) will be reduced.

RECOMMENDATIONS

There are numerous manufacturers currently producing rock removal devices, all of which are properly designed to accomplish the specific task or removing rocks from on or near the surface. The simplest type, which has no penetration or separation capabilities, accomplishes the elimination of surface rock problems. These basic machines are affordable, effective, practically maintenance free, have a definite market, and there is little, if anything, that can be done to improve their design or demand. In view of this, no recommended changes can be made in the design of direct loading (passive rake variety) type rock pickers. The larger more sophisticated rock pickers have also reached near optimum development for their standard designs. While minor refinements could be made to some models for special conditions, these would only result in slight improvements.

Significant improvements in rock removal technology will, therefore, require innovative concepts to be implemented. Yet, until a more positive demand becomes apparent to the rock picker manufacturers, fundamental research and development (R & D) of new concepts will not be done. Since present technology meets the current market demand, as well as being adequately functional, it seems that a more difficult application must be required on a large scale. Thus, a new, more demanding rock removal problem would have to be introduced. Such an impetus would most likely be initiated as a side affect of an attempt to rehabilitate abandoned mined areas.

Typical conditions of an abandoned mined lands present a severe challenge to reclamation efforts. The unsegregated overburden spoil piles contain overturned strata that is hopelessly mixed together. Topsoil buried under these piles are adversely affected by the resultant suffocations, leaching, and rock contamination. With the exception of those areas having naturally abundant rock free soils (20-40 feet thick), very little suitable topsoil material can be spread over the regraded areas. Depending on the natural topsoil availability, the contractor must choose between purchasing topsoil elsewhere or salvaging the original soils.

Recent federal regulations require that states submit a reclamation plan for their abandoned mined lands. A specialized reclamation device could have great potential to help achieve this reclamation. However, these two facts alone won't be able to demonstrate the available market that is required to convince manufacturers to invest their money in developing new machinery. The research and development can only be stimulated by offering R & D funds in the form of grants or demonstration projects. The justification for such funding will also need to be shown. By examining the funding that will be required to reclaim the nation's abandoned mined lands, a substantial savings may be able to be predicted as a result of developing a more cost efficient way of procuring sufficient quantities of topsoil material that will insure an acceptable revegetation.

Currently, many states are taking inventories of their abandoned mined lands. A guide, which will help states formulate their required abandoned mined lands plan, was recently completed by Skelly and Loy and is entitled "Approaching an Abandoned Mined Lands Reclamation/Development Plan". The site specific information gathered in preparation of these plans could be used to study the cost effectiveness of developing and employing a new rock removal concept.

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LISTS OF MANUFACTURERS

TABLE 6

ROCK PICKER MANUFACTURERS

Armor Metal Products
Helena, Montana 59601
Tel. (406) 442-5560

Bestland
Viel Manufacturing Co.
P.O. Box 632
Billings, Montana 59103
Tel. (406) 252-6808

Degelman Industries Ltd.
P.O. Box 480 Industrial Drive
Regina, Saskatchewan, Canada S4P3B1
Tel. (306) 543-4447

Harley Rock Picker Co.
Clarissa, Minnesota 56440
Tel. (218) 756-2378

Imperial Welding & Machine, Ltd.
Saskatchewan, Canada
Tel. (306) 653-0992

Leon's Manufacturing Co. Ltd.
Yorkton, Saskatchewan, Canada 53N2X3
Tel. (306) 783-6592

Lockwood Corp.
Box 160
Gering, Nebraska 69341
Tel. (308) 436-5051

McConnell Manufacturing Co. Inc.
McConnell Avenue
Prattsburg, New York 14873
Tel. (607) 522-3701

Melroe Division
Clark Equipment Co.
Gwinner, North Dakota
Tel. (701) 222 5000

TABLE 8 (Cont'd.)

ROCK PICKER MANUFACTURERS

N. D. Nelson
17 Valley Road
Butler, New Jersey 07405
Tel. (201) 838 0173

Pratt Farms
Box 197
Aberdeen, Idaho 83210
Tel. (208) 397 4662

Rockland Manufacturing Company
P.O. Box 5
Bedford, Pennsylvania 15522
Tel. (814) 623 1115

Rock-O-Matic
R. Bussieu & Sons
P.O. Box 117
Vonda, Saskatchewan, Canada
Tel. (306) 258-2074

Schulte Industries Limited
P.O. Box 70
Englefeld, Saskatchewan, Canada
Tel. (306) 287-3155

Steinman Mfg. Div.
P.O. Box 397
Canington, North Dakota
Tel. (701) 652-3197

Thomas Equipment Ltd.
P.O. Box 130
Centreville, New Brunswick, Canada
Tel. (306) 276-4511

Westgo Industries
West Fargo and Minot, North Dakota
Tel. (701) 282-3277

Wisconsin Rock Harvester
Route 1 Box 188
Wisconsin Rapids, Wisconsin 54494
Tel. (715) 421-2992

TABLE 7

ROCK RAKE MANUFACTURERS

Austin Products Inc.
P.O. Box 22217
Dallas, Texas 75222
Tel. (214) 651 0733

Brillion Iron Works
Brillion, Wisconsin 54110
Tel. (414) 756 2121

Degelman Industries Ltd.
P.O. Box 480 Industrial Drive
Regina, Saskatchewan, Canada S4P3B1
Tel. (306) 543-4447

Fleco Corporation
Jacksonville, Florida
Tel. (904) 354 8361

Rockland Manufacturing
P.O. Box 5
Bedford, Pennsylvania 15522
Tel. (814) 623-1115

York Modern Corporation
Unadella, New York 13849
Tel. (607) 369 2631

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TOPSOIL ROCK REMOVAL TECHNOLOGY

APPENDICES

PREPARED FOR THE **UNITED STATES BUREAU OF MINES,**
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ENGINEERS-CONSULTANTS, HARRISBURG,
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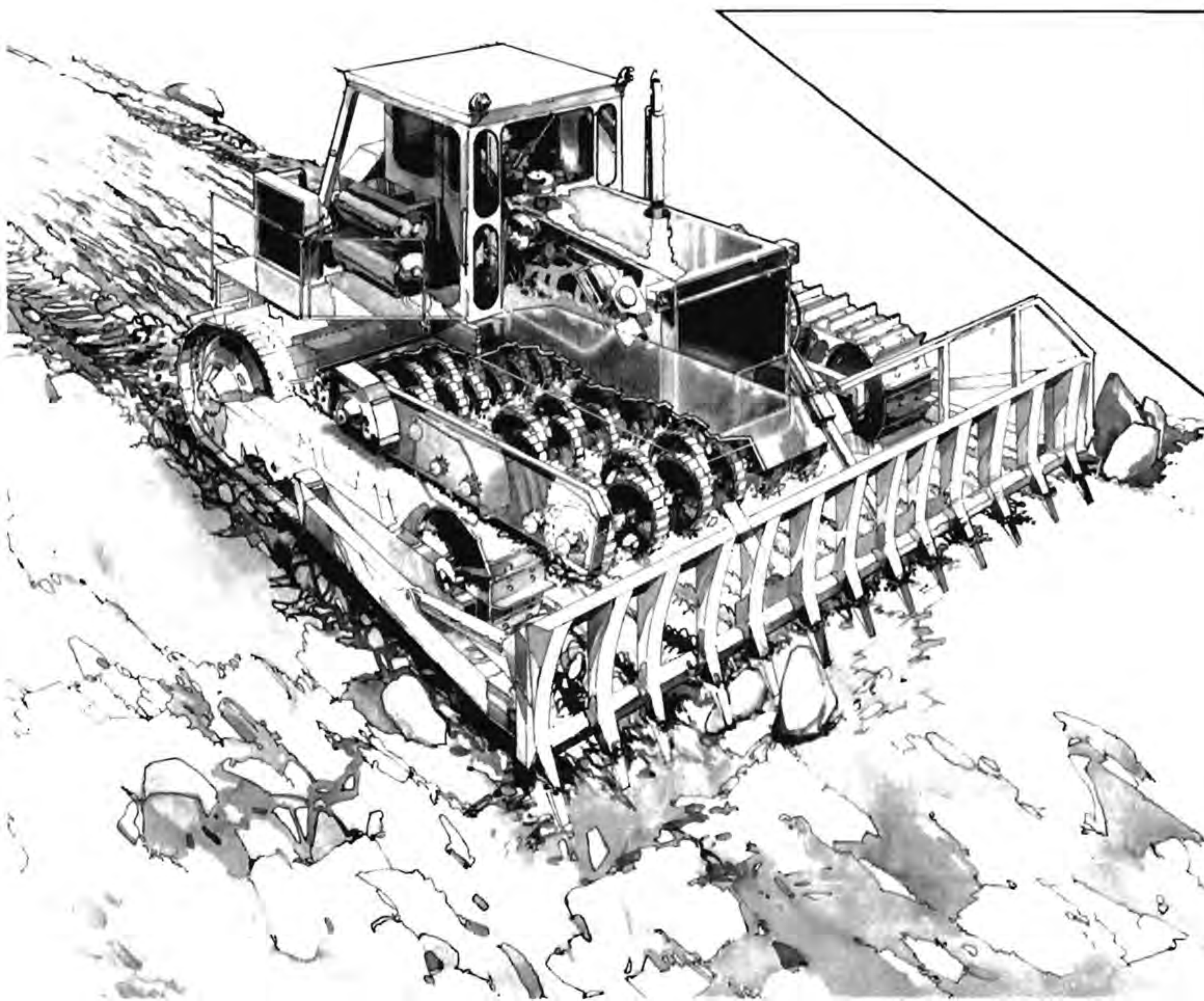

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TOPSOIL ROCK REMOVAL TECHNOLOGY

APPENDICES CONTRACT #J0285023

PREPARED FOR:

THE UNITED STATES BUREAU OF MINES

Section of Contracts, Building 20
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October 1979

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15. Supplementary Notes

16. Abstracts

This report summarizes a study conducted to determine the state of the art of various rock removal systems and their capabilities. The objective of the study was to determine if currently manufactured equipment can adequately accomplish rock removal in surface mine reclamation applications. Evaluations of state reclamation regulations, with regard to topsoil rock content, were made to determine the rock removal require ments. The major categories of equipment studied are rock pickers and rock rakes.

The impact of rock removal implementation on the reclamation operations is discussed in detail.

17. Key Words and Document Analysis. 17a. Descriptors

Rocks, stones, rock pickers, rock rakes, topsoil, topsoil handling, surface mine reclamation, topsoil rock content, and rock content regulations in U.S. coal states.

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

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FORLWORD

This report was prepared by Skelly and Loy, Engineers and Consultants, 2601 North Front Street, Harrisburg, Pennsylvania, under USBM Contract Number J0285023. The contract was completed under the Mining Environmental Research Program. It was adminis tered under the technical direction of Spokane Mining Research Center with Mr. Thomas Brady as Technical Project Officer. Ms. Darlene Wilson was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period October 1, 1978 to September 30, 1979. This report was submitted by the authors on October 31, 1979.

TABLE OF CONTENTS

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INTRODUCTION

INTRODUCTION

This volume contains all the economic analyses compiled during this study. The economic impact on specific reclamation unit operations costs was evaluated.

A unit operations cost breakdown is included for seven of the nine mine sites studied, while two selected mines were defined by a complete cash flow analysis.

All economic evaluations were made using 1979 costs and future references to this data must apply correction factors to account for the effects of inflation on labor, equipment costs, and fuel.

SENSITIVITY ANALYSIS

SENSITIVITY ANALYSIS

Introduction

There are several methods available for evaluating the unknowns involved in investment decisions. The sensitivity analysis approach is one way in which to quantitatively incorporate risk and uncertainty into analyses.

This approach refers to the relative magnitude of the change in one particular element which can be varied over a wide range of values without drastically affecting the desired result, the situation is said not to be sensitive to uncertainties regarding that particular element. On the other hand, if a small change in the estimate of one element will drastically affect the desired result, the situation is said to be very sensitive to changes in the estimates of that element.

Some typical parameters that often are allowed to vary for sensitivity analysis include initial investment, selling price, operating cost, project life and salvage value. In this study, the sensitivity analysis was performed on the topsoil removal and reclamation costs per acre.

Variable Parameter Descriptions

In order to determine the affects of implementing a rock picker into the reclamation plans of Case History Mines #8 and #9, a sensitivity analysis was performed. Keeping certain criteria constant and varying those items which would most likely fluctuate, sensitivity graphs were constructed. Criteria held constant throughout this analysis were:

1. 6 inch effective penetration depth of rock picker
2. 8 foot effective picking width
3. 5 mph ground speed during dumping cycle
4. 60 second dump cycle
5. \$30,000 cost for rock picker and tractor
6. 7¼ hour shifts
7. UMW operator for tractor (Grade 1)
8. 90% availability of rock picker and tractor

Items considered as variable were:

1. Operating speed varying from 1 to 5 mph
2. Hopper capacity varying from 4 to 16 cubic yards
3. Haul distance to dump varying from 0 to 5000 feet
4. Hopper versus direct loading

For each mine site, one of the above items was varied while the other items remained constant. The corresponding topsoil removal and reclamation cost per acre was calculated for each combination. Graphs were plotted for each mine site with the percent rock on the horizontal axis (varied from 0 to 20%), and the corresponding reclamation cost per acre on the vertical axis. The four different parameters which affect rock picker operating costs were all subjected to this procedure.

The following graphs were completed for Case History Mine #8, (a 190 acre area mine producing 1,350,000 tons of coal per year) and Case History Mine #9, (a 30 acre mine producing 147,000 tons of coal annually). Each graph illustrates mine costs without a rock picker, as well as the variable costs when a rock picker is included. Topsoil removal and reclamation costs for Case History Mine #8 were \$18,440 per acre and for Case History Mine #9 they were \$25,530 per acre. Resultant costs for including a rock picker began at 5%, since an area with a rock content less than 5% will not benefit from the services of a rock picker.

The basic assumptions for determining the rock picker's cycle time were a 5 mph operating speed, 4 cubic yard hopper capacity, 5000 foot average haul distance, and hopper loading (instead of direct loading to trucks).

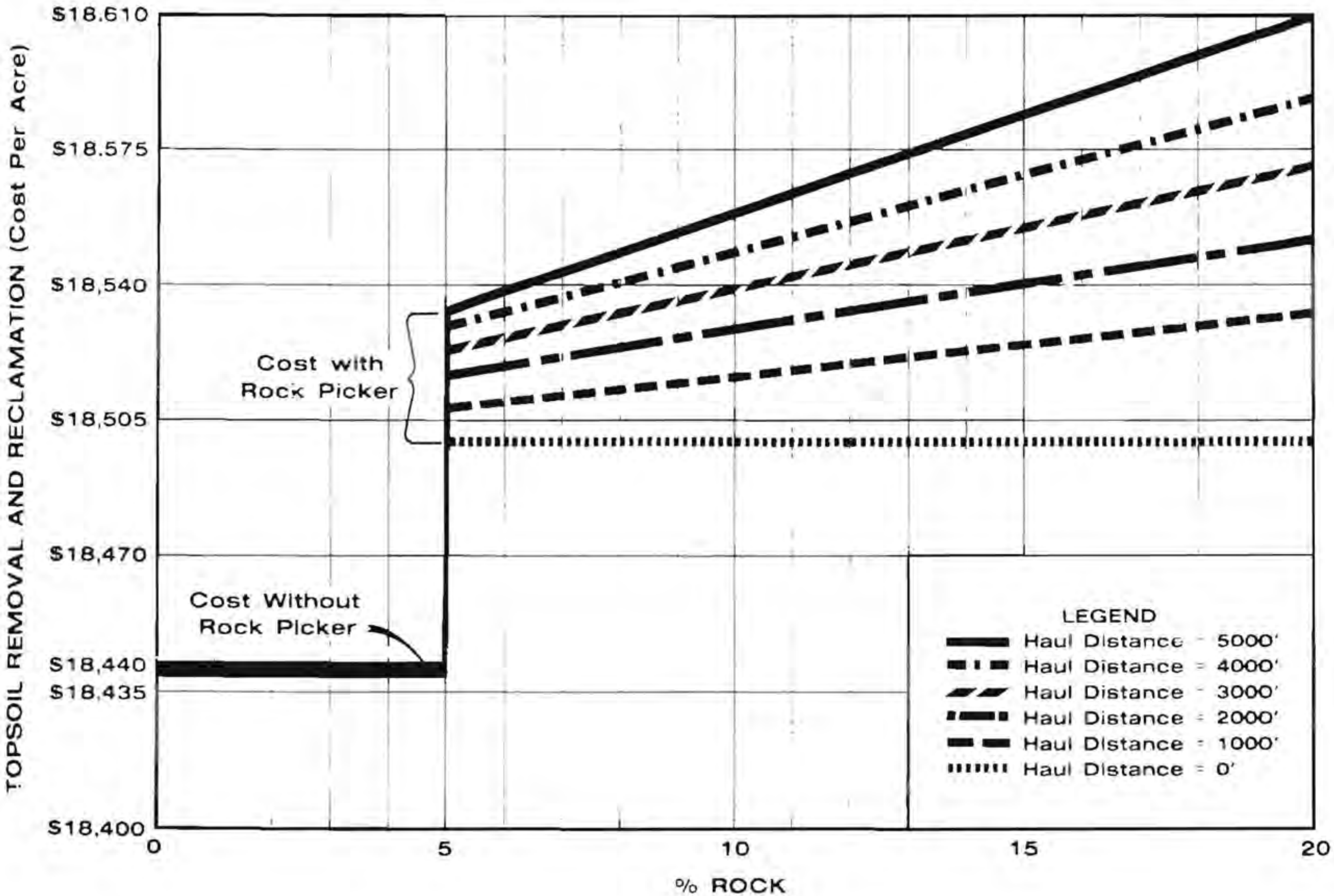
Varying Haul Distance

Figures 1 and 2 reveal that as the haul distances increase from 0 to 5000 feet and the percent of rock increases from 5 to 20%, the costs per acre also increase. This is a directly proportional relationship. The costs per acre are increasing due to the increasing cycle time. As the percent of rock content increases, the number of times the dumping cycle must take place is increased. Also, as haul distances increase, cycle times increase resulting in lower production rates.

From Figure 1 it can be seen that at an 8% rock content and a 4000 foot haul distance, costs per acre were calculated to be approximately $18,540. The percent of difference between this new cost and the cost without a rock picker is 0.54%, which is a very minor change.

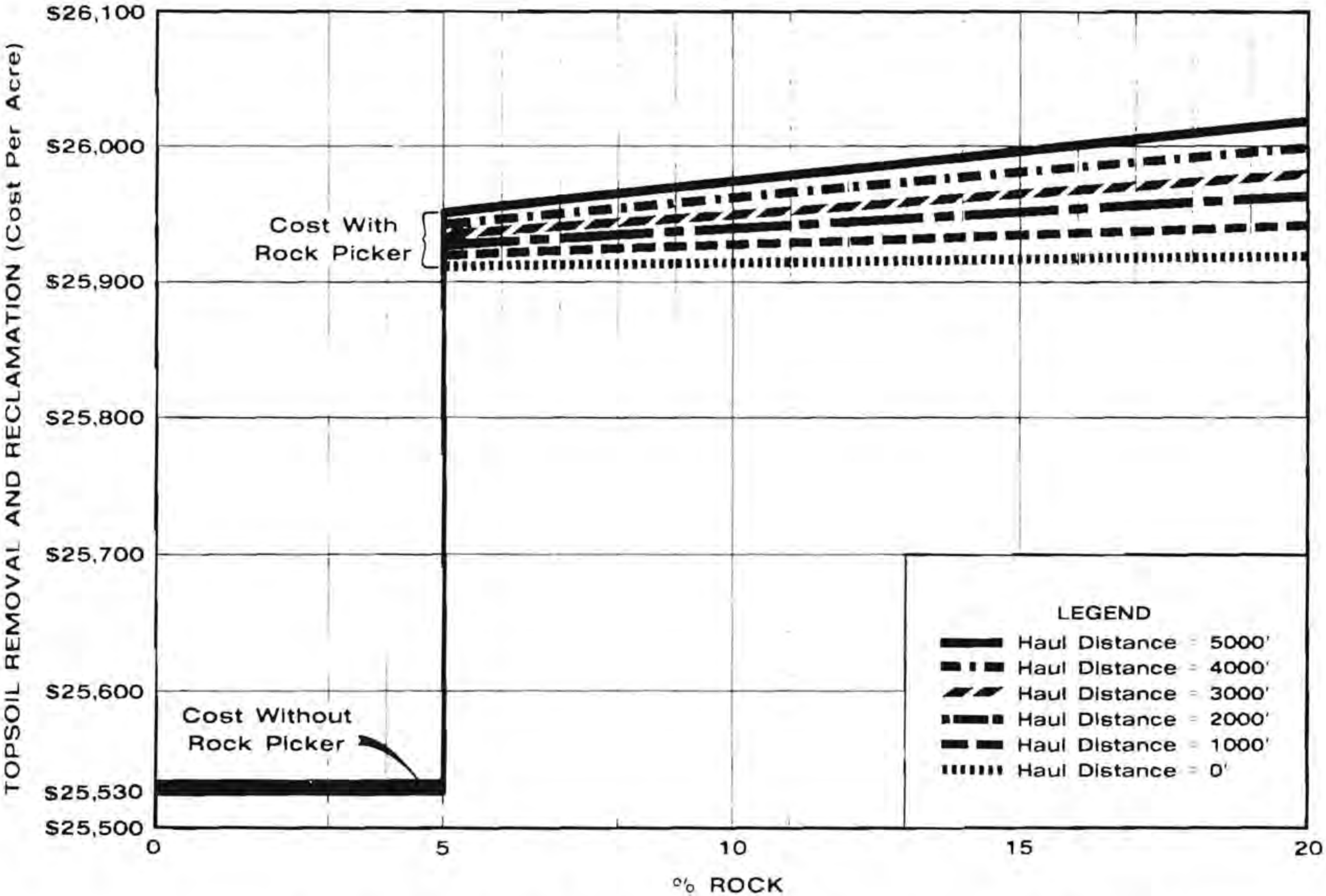
On Figure 1 the percent of difference between the maximum rock picker of $18,610 and the cost without a rock picker is 0.91%, while Figure 2 shows a 1.92% difference. Both of these changes are minimal and the relationships can be considered to be very insensitive.

Also, as the haulage distances decrease, the higher rock content has less of an effect on productivity due to the faster cycle times. This end result is the reason for the slopes of the lines being flatter as the haul distances decrease.



CASE HISTORY MINE #8 - RECLAMATION COST/ ACRE VS % ROCK (Varying Haul Distance)

FIGURE 1



CASE HISTORY MINE #9 - RECLAMATION COST/ ACRE VS % ROCK (Varying Haul Distance)

FIGURE 2

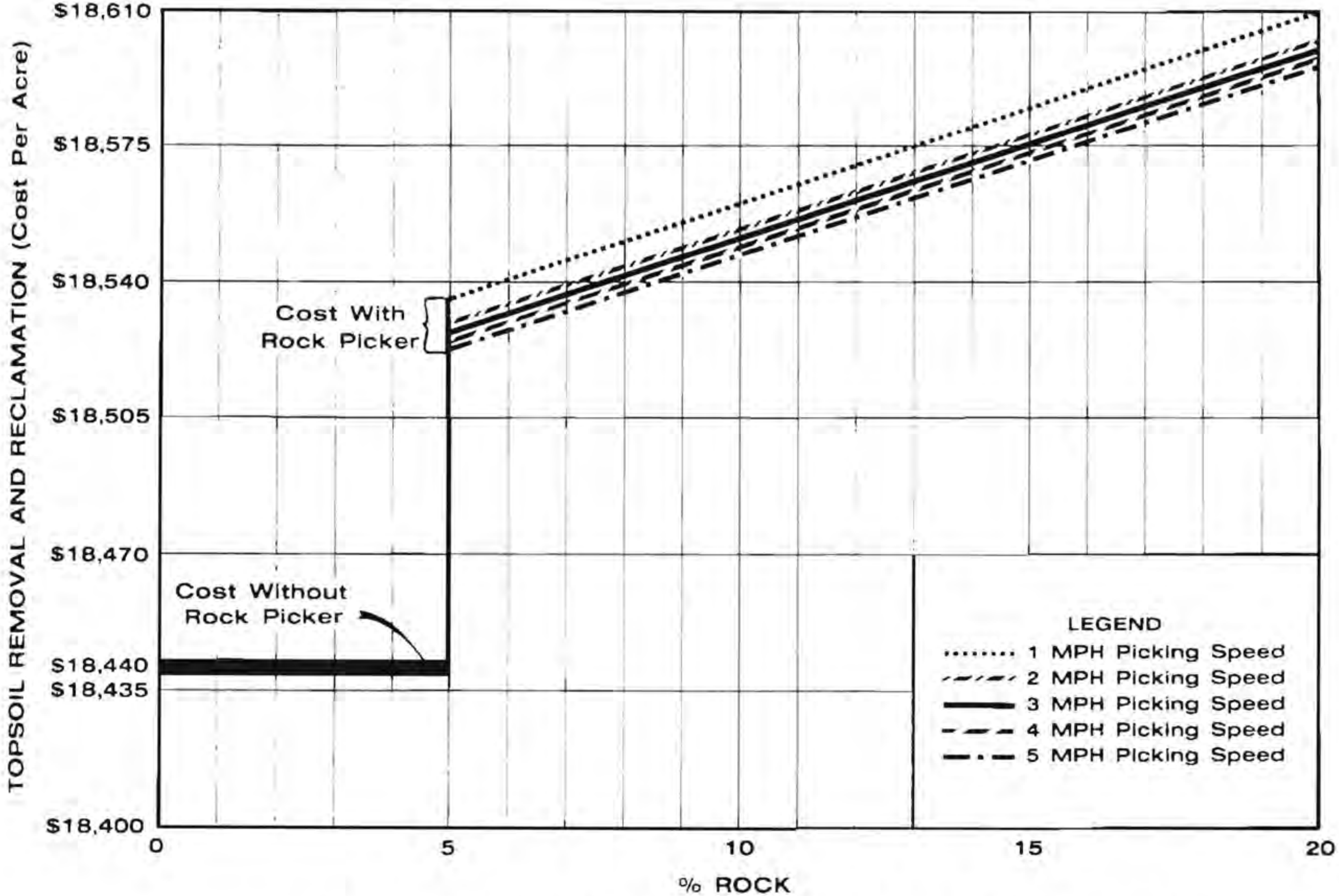
Varying Operating Speed

The graphs presented in Figures 3 and 4 illustrate the relationship of operating speed, percent rock, and costs per acre for reclamation and topsoil removal. Picking speeds range from 1 to 5 mph and, again, rock content ranges from 5 to 20%. This cost to speed relationship is inversely proportional, in that, as the speed is increased the costs per acre decrease. This is due to higher speeds causing shorter cycle times and consequential higher productivity. The percent of rock to cost relationship is directly proportional for reasons explained in the previous section.

From Figure 3, it can be seen that for a 10% rock content and a picking speed of 3 mph, topsoil removal and reclamation costs will be approximately $18,540 per acre. The percent of change here is only 0.54%. Overall percent changes in Figures 3 and 4 are the same as in the previous section, again revealing a highly insensitive situation.

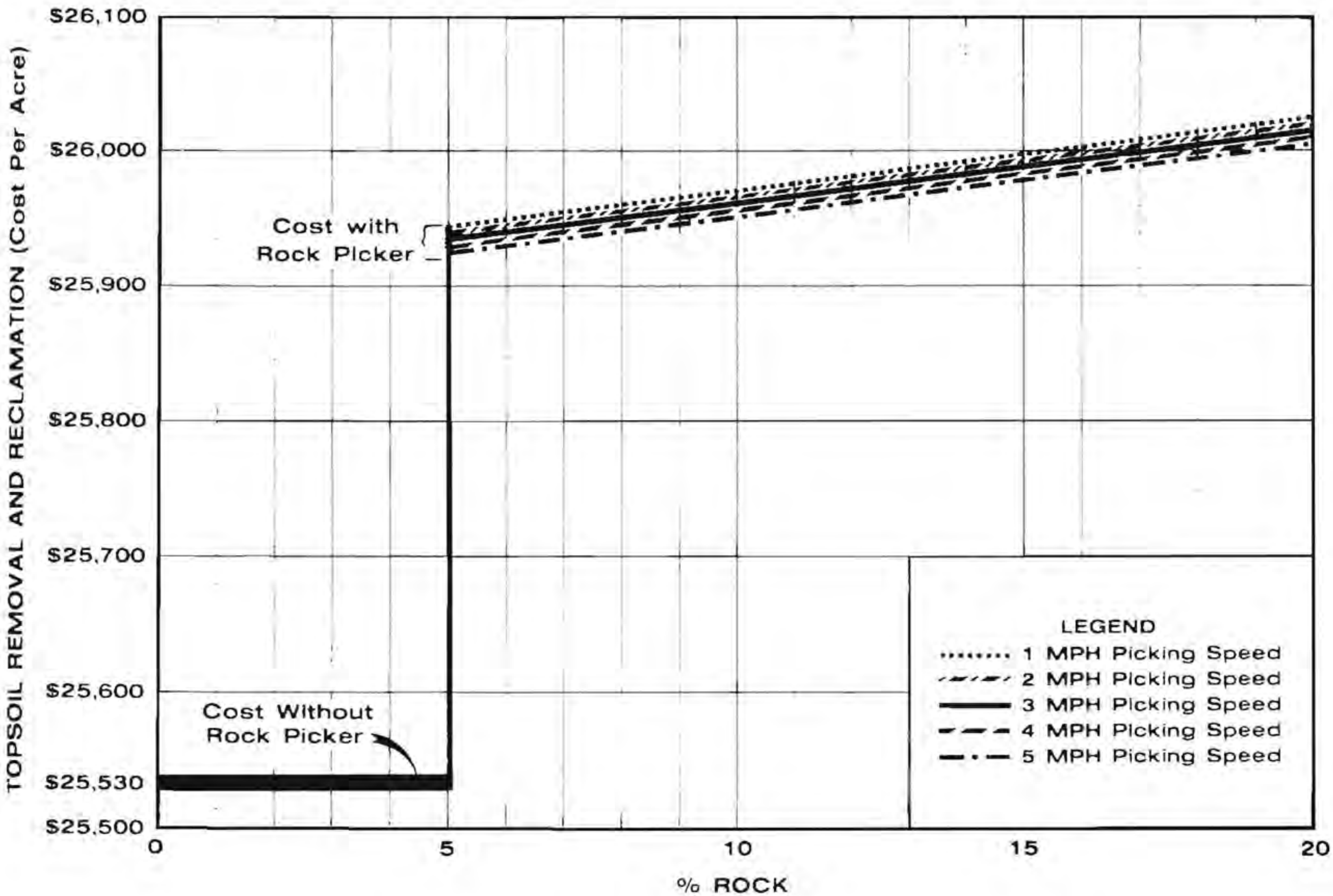
Varying Hopper Capacity

Different hopper sizes on the rock picker will definitely affect production, for obvious reasons. Larger hopper capacities result in higher productivity. Cycle times are essentially the same using large or small hoppers; however, more material is transported with the larger ones, resulting in the higher productivity. Figures 5 and 6 are graphs depicting the results of varying the hopper capacity from 4 to 16 cubic yards. Another inversely proportional relationship is exemplified here, in that, as hopper



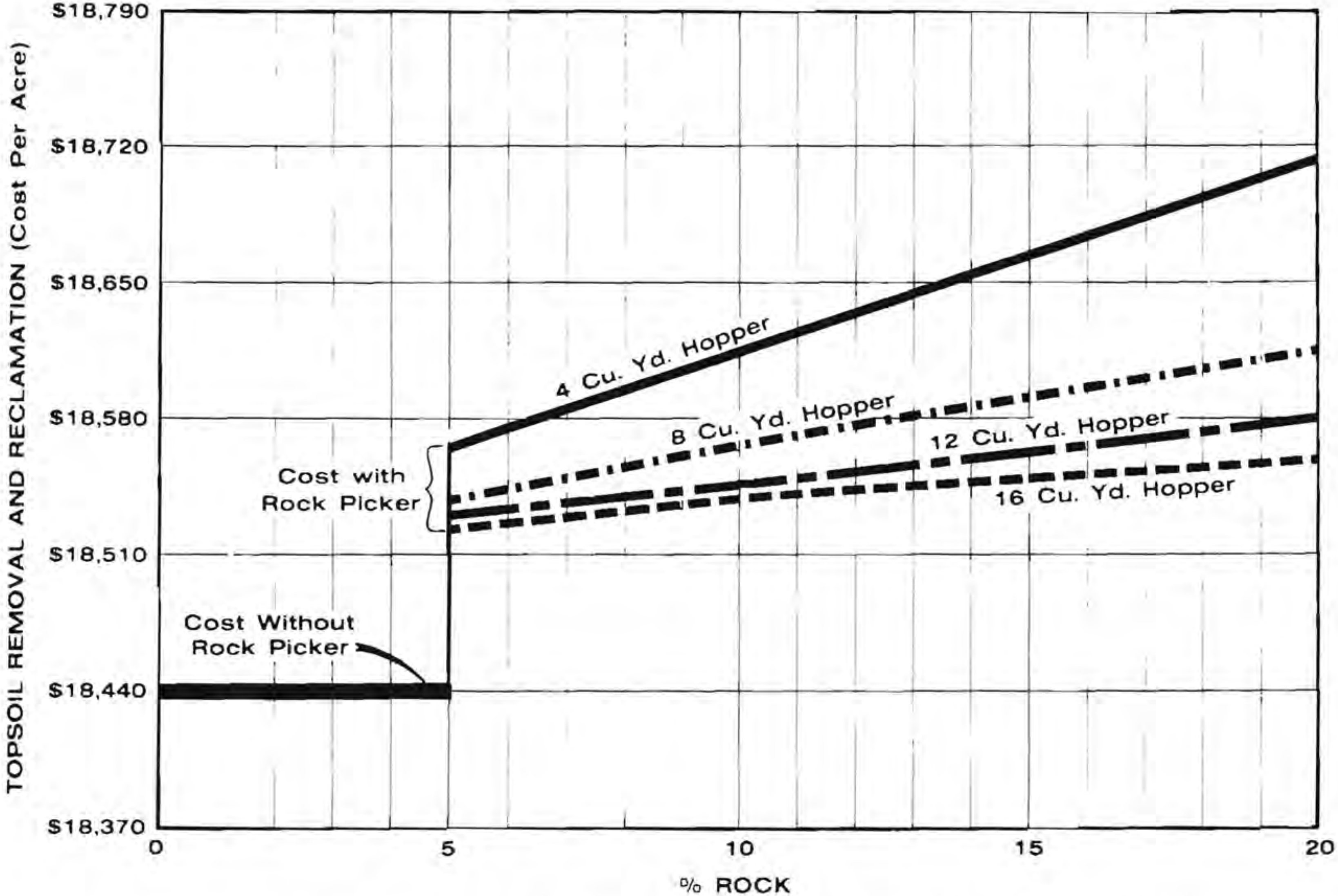
CASE HISTORY MINE #8 — RECLAMATION COST/ ACRE VS % ROCK (Varying Operating Speed)

FIGURE 3



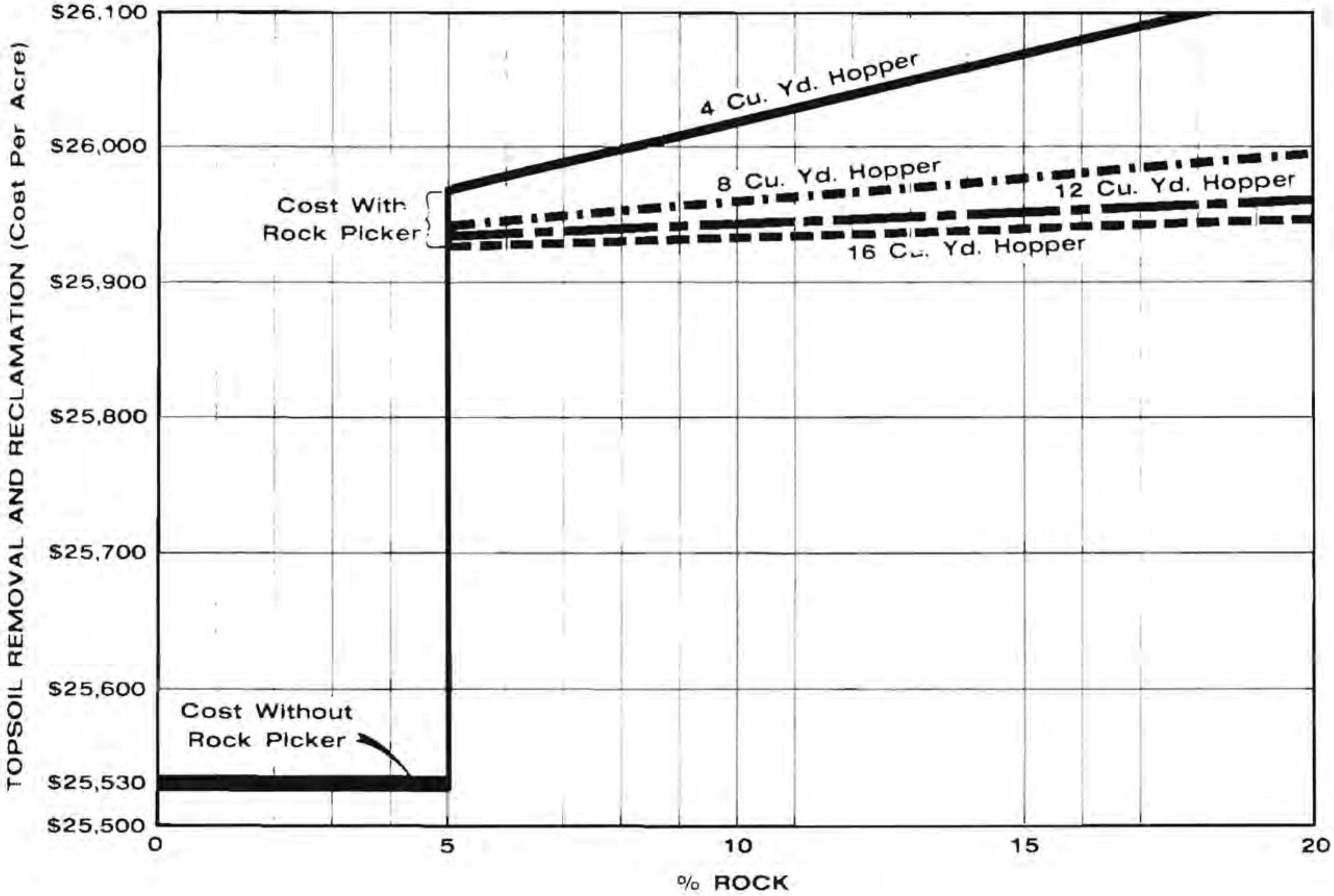
CASE HISTORY MINE #9 - RECLAMATION COST/ ACRE VS % ROCK (Varying Operating Speed)

FIGURE 4



CASE HISTORY MINE #8 - RECLAMATION COST/ ACRE VS % ROCK (Varying Hopper Capacity)

FIGURE 5



CASE HISTORY MINE #9 - RECLAMATION COST/ ACRE VS % ROCK (Varying Hopper Capacity)

FIGURE 6

capacity increases, costs per acre decrease, due to the increased productivity. Again, as in the other sections, as the percent of rock increases, topsoil removal and reclamation costs per acre increase.

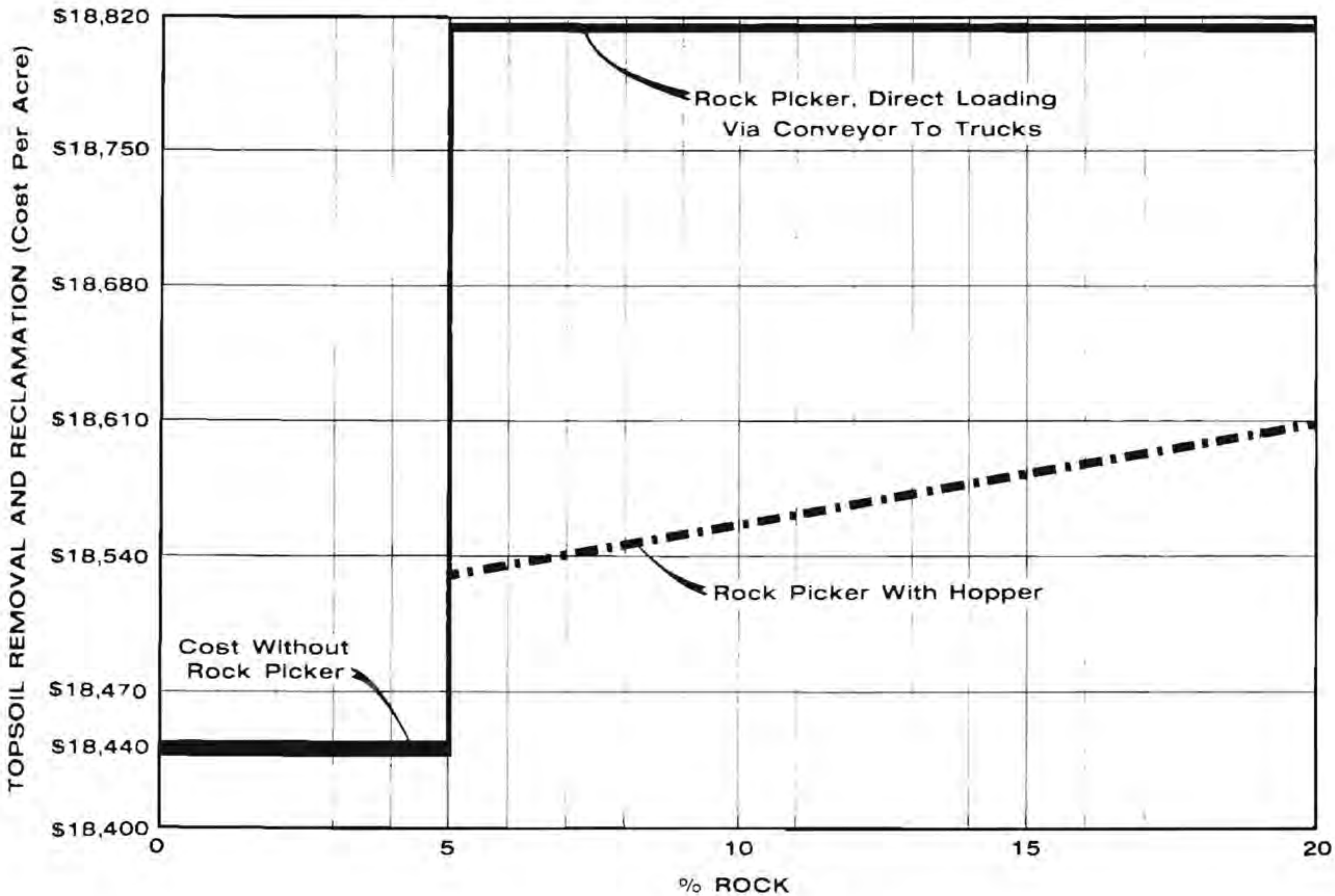
Figure 5 shows a 1.52% difference between the highest rock picker cost and the cost without a rock picker. Figure 6 reveals a 2.31% difference. A highly insensitive situation is again revealed here as in the previous graphs.

The flattening slopes of the higher hopper capacity lines is due to the void ratios having less of an effect in the larger hoppers than in the smaller hoppers. The percent of void space would be less in the 16 cubic yard hopper enabling even more production capacity than a straight line relationship would reveal.

Hopper vs Direct Loading

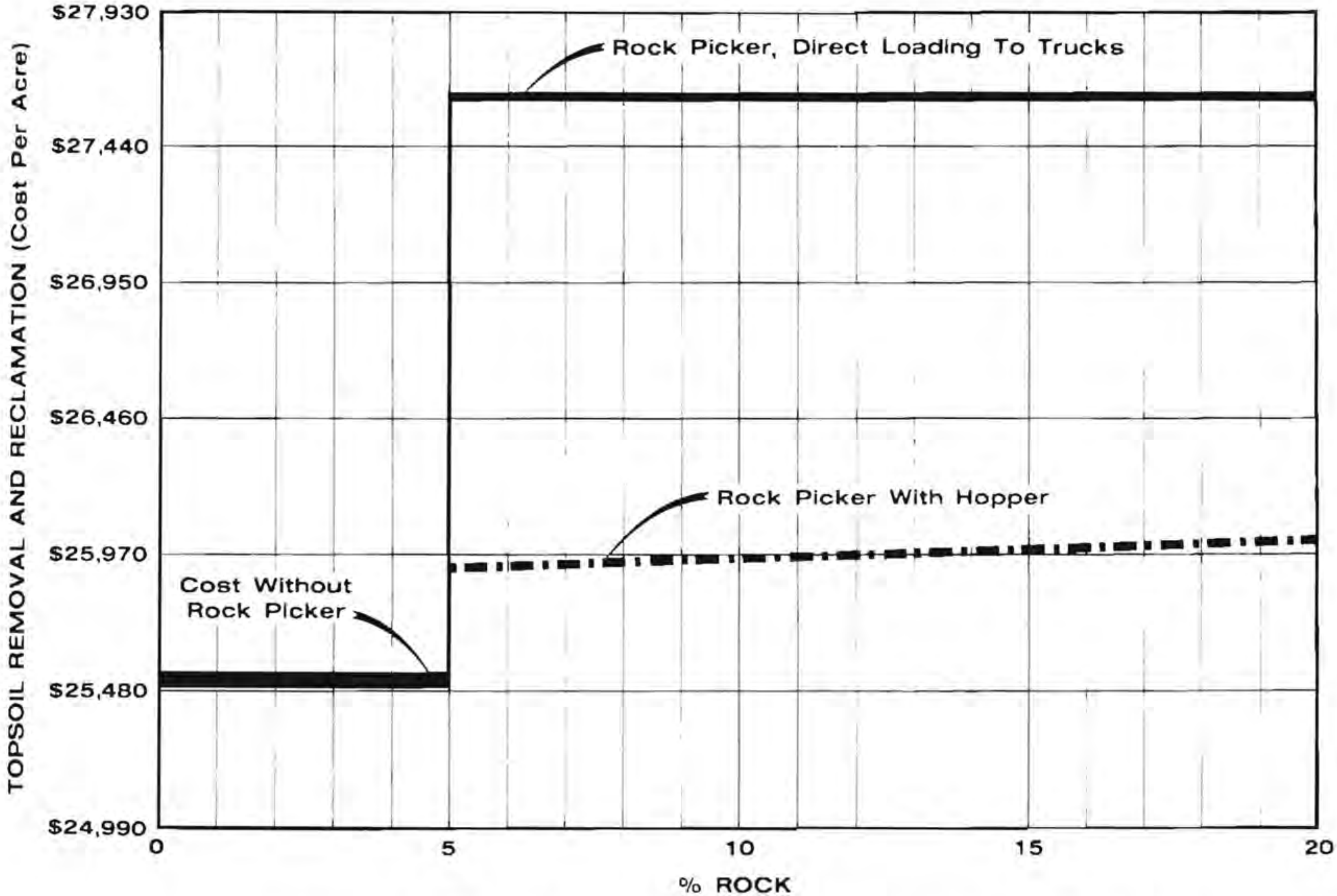
Utilizing continuous direct loading to trucks for material transportation (as opposed to hopper loading) reveals a higher cost due to the additional equipment required. This is illustrated in Figures 7 and 8. By comparing these costs for Case History Mine #8 reveals a 2.00% difference utilizing truck haulage and a 0.92% difference utilizing hopper loading (assuming a 4 cubic yard hopper, 5000 foot haul distance, and a 5 mph picking speed).

The same assumptions were used for Case History Mine #9 in Figure 8 for the rock picker and trucks. The percent of differences here were 8.37% and 2.14% between rock picker costs using truck hauling or hopper loading, and costs without a rock picker respectively.



CASE HISTORY MINE #8 - RECLAMATION COST/ ACRE VS % ROCK (Hopper vs Direct Loading)

FIGURE 7



CASE HISTORY MINE #9 - RECLAMATION COST/ ACRE VS % ROCK (Hopper vs Direct Loading)

FIGURE 8

All of the figures for these relationships still reveal an insensitive situation. The Case History Mine #9 difference of 8.37% for truck loading is higher than the previous differences, but it is still below 10%, which is considered a tolerable range.

Worst Case Analysis

When estimating the impact of additional or innovative equipment (or concepts) on the overall operation, sensitivity analysis reveals areas where adjustments could be made for estimating purposes, if the end result is highly sensitive with respect to that particular factor. Further investigation into evaluation could be accomplished by a worst case analysis. When conducting a worst case analysis, the objective is to define the most adverse set of circumstances that could feasibly be encountered during the unit operation.

The rock picker portion of the topsoil removal and reclamation cost for both selected case history mines was subjected to a worst case analysis to determine the net effect on the overall operating cost per ton. Factors selected to depict the worst case were a 1 mph operating speed, 4 cubic yard hopper capacity, 5000 foot haul distance, 20% rock content, and direct loading into trucks.

Applying these factors to Case History #8 operating cost per ton of $15.166 compared with $15.111 per ton without a rock picker, the difference is $0.055 per ton or 0.36%. Case History Mine #9 resulted in a $0.418 per ton increase or a 1.48% difference (from the $28.231 to $28.648 per ton increase).

As can be seen from the above figures, the incorporation of a rock picker into an operator's reclamation plan results in a minimal additional cost.

Required operating time is also low and readily sequenced into normal reclamation activities. By using a worst case situation (assuming: 1 mph picking speed, 5 mph dump speed, 5000' to dump site, 8' swath, 8 cy hopper, and 6" penetration) it takes 9 hours to clear 1 acre of land that contains 20% of rock content. Assuming the same operating specifics, yet using a more conservative 10% rock content, will require only 5 hours per acre.

Some benefits to be realized would be improving the value of the land, increasing crop yield, improving aesthetics, and favorable public reaction to a company genuinely interested in improving post-mined lands and uses.

Projected Rock Picker Costs

Table 1 presents the topsoil removal and reclamation costs with projected rock picker costs for the other seven mine sites visited. Unit costs for topsoil removal and reclamation for the seven sites are developed in Appendix A. Cost data obtained from the sensitivity analysis were used to compute the projected rock picker costs.

Table 1 shows a $1220 average increase per acre by implementing a rock picker into the reclamation plan. To arrive at this cost the worst possible results from the sensitivity analysis were used. Since this will not always occur, and, with so many variables to affect the actual topsoil removal and reclamation costs, a more realistic increase would be in the range of $600 to $900 per acre..

Also included in Table 1, are topsoil removal and reclamation costs per ton of coal with and without the addition of a rock picker. Since the tons of coal produced from an acre of land can vary markedly, the extrapolated increase of $.24 per ton is an ambiguous estimate at best. A realistic increase in dollars per ton would be in the range of $.05 to $.40.

TABLE 1

TOPSOIL REMOVAL AND RECLAMATION COSTS WITH PROJECTED ROCK PICKER COSTS

MINE SITE	COST WITHOUT ROCK PICKER		PROJECTED COST WITH ROCK PICKER	
	$/Acre	$/Ton	$/Acre	$/Ton
CH-1	6,300	0.71	7,520	0.94
CH-2	9,320	2.05	10,500	2.29
CH-3	5,570	1.48	6,790	1.72
CH-4	17,600	1.65	18,800	1.89
CH-5	3,060	1.50	4,280	1.74
CH-6	3,220	2.31	4,440	2.55
CH-7	3,750	1.67	4,970	1.91
AVERAGE	6,970	1.62	8,190	1.86
AVERAGE INCREASE	—	—	1,220	0.24

APPENDICES

APPENDIX A

CASE HISTORY MINE #1

General Mining Description

This mine site is located in central Indiana along the eastern edge of the Eastern Interior Coal Basin. Geographically located within a prime farmland region, the terrain is flat with abundant thickness of soils.

Area mining is conducted to recover the Seelyville coal seam at a strip ratio of 20:1 on a dip of less than 2° to the west. Typical overburden characteristics at this mine are approximately 6 feet of loess, 25 feet of glacial till, and 65 feet of shale. The Seelyville averages 5 feet in thickness and consists of 11.3% moisture, 11.2% ash, 3.05% sulfur, and a BTU value of 11,080. This mine affects and reclaims 117 acres/year to produce an average of 1,038,000 tons.

The topsoil (12 inches) is removed by scrapers and stockpiled. Overburden removal and replacement is accomplished by a Bucyrus Erie 2570 dragline. The coal is loaded out by a Marion shovel into over the-road haul trucks to a nearby plant.

TABLE A-1

CASE HISTORY #1
UNIT OPERATIONS COST

Topsoil Removal and Reclamation

Equipment & Materials		Cost/Year
4 Bulldozers		$224,000
4 Scrapers		248,000
1 Hydroseeder & Tractor		4,200
1 Farm Tractor (Int. H.)		2,200
Fuel		
Bulldozers ($7.95/hr. x 1,152 hrs./yr.)		$ 9,200
Scrapers ($8.06/hr. x 1,152 hrs./yr.)		9,300
Hydroseeder & Tractor ($2.02/hr. x 1,152 hrs./yr.) Int. H. Farm Tractor		2,300
Seed (117 ac. @ 35 lbs./ac. x $0.70/lb.)		2,900
Fertilizer (117 ac. @ 1,000 lbs./ac. x $0.04/lb.)		4,700
Labor and Operator Cost		
Bulldozer Operators		$ 43,100
Scraper Operators		43,100
Revegetation Equip. Operators		15,100
	Subtotal =	$608,000
Auxiliary Operations		
Strip License and Reclamation Fee		$ 37,900
Miscellaneous Equipment, Overhead and Supervision (608,100 x .15)		$ 91,200
	Total Unit Cost =	$737,000
	Cost/Acre =	$ 6,300
	Cost/Ton =	$ 0.71

CASE HISTORY MINE #2

General Mining Description

Mine #2 an area mine, is located in the western portion of the Illinois coalfields. Topography at this site is typical of the prime farmland region, flat to gently rolling. Large farm tracts and pastureland dominate the area adjacent to the mine operation. Annual mean temperatures range from 42° to 62°. Total precipitation varies from 36 to 48 inches yearly, with some storms providing 2 to 3 inches in a 24 hour period. The Harrisburg Springfield (No. 5) coal seam is mined in three separate pits at this operation. Coal characteristics are: 10,400 BTU; 9-12% ash; 3% sulfur and 42% fixed carbons. The No. 5 seam averages 60 inches in thickness. The expected life at this site is 10 years with an estimated reserve of 10 million tons.

Mining activities commence with the clearing and grubbing of small clusters of trees that are open burned. Dozers and scrapers remove and stockpile 18 inches of A Horizon and 2.5 feet of B and C Horizons. Then twenty to forty feet of glacial material is removed by a bucket wheel excavator with the spoil being directly cast across the pit. Working in conjunction with the BWE is a 40 cubic yard stripping shovel which excavates 50 to 60 feet of shale overlying the coal.

Bulldozers equipped with single shank rippers are used to loosen the coal for loading with a 10-12 cubic yard loading shovel, the haul units transport the coal to the coal preparation plant. After processing, the coal is shipped by unit trains and sold as steam coal.

Reclamation equipment follows the stripping operation by a minimum of three spoil piles. Bulldozers grade the spoil piles and scarify the surface, while pushing large rocks and boulders into the spoil pile furrows for burial. Scrapers replace the sub-soils first and then the A horizon. On an average, 20 lbs. of grasses and legumes per acre are applied by aerial seeding. After about two years, the soil has assumed a new structure and row crops may be planted. The total reclaimed acreage per year is an approximated 220 acres. Annual production averages 1,000,000 tons.

TABLE A-2

CASE HISTORY #2
UNIT OPERATIONS COST

Topsoil Removal & Reclamation

Equipment & Materials		Cost/Year
4 Bulldozers (D-8)		$ 223,000
1 Bulldozer (D-7)		61,200
5 Scrapers (637 Cat)		517,000
1 Scraper (633 Cat)		91,700
Fuel		
Bulldozers (D-8) ($5.82/hr. x 2,760 hrs./yr.)		$ 64,600
Bulldozers (D-7) ($3.88/hr. x 2,760 hrs./yr.)		10,700
Scrapers (637) ($8.06/hr. x 2,760 hrs./yr.)		111,000
Scrapers (633) ($8.06/hr. x 2,760 hrs./yr.)		22,200
Seed & Fertilizer		
(Aerial — Contracted Out @ $27.00/Ac. x 220 Ac.)		$ 5,900
Labor and Operator Cost		
Bulldozer Operators (5)		$ 129,000
Scraper Operators (6)		154,000
	Subtotal =	$1,390,000
Auxiliary Operations		
Strip License and Reclamation Fee		$ 451,000
Miscellaneous Equipment, Overhead and Supervision (1,390,000 x .15)		209,000
	Total Unit Cost =	$2,050,000
	Cost/Acre =	$ 9,320
	Cost/Ton =	$ 2.05

CASE HISTORY MINE #3

General Mining Description:

Mine #3 is located in southern Illinois. The surrounding topography represents typical Midwestern terrain with approximately 50% timberland, 25% pasture, and 25% marginal cropland. The Midwest climate of this area (50° average temperature and 35 inches average annual precipitation) causes the usual problems associated with weather (muddy haul roads, water in the pit, etc.). The one minable bituminous coal seam at this site is the Herrin (or No. 6 seam), which is 54 inches thick. This seam has a general post-preparation quality of 12,000 BTU, 8.5% ash and 2% sulfur and is utilized in steam power electric generators.

The average overburden thickness above the No. 6 seam is 70 feet and is composed of 1 4 feet of topsoil, 6-7 feet of decomposed shale, 4-6 feet of limestone and 54 feet of medium to hard shales. These moderately bedded rock systems are consolidated enough to warrant 10 3/4 inch drill holes on a 24 x 24 foot grid pattern, and blasting with 600 pounds of ammonia nitrate mixed with diesel fuel (ANFO) per hole. Overburden handling at this mine is typical of the Midwest's area mining methods. Through the use of a dragline directly casting into their previously mined out pits or, when higher overburden depths are encountered, stripping shovels are incorporated to assist in overburden removal. Normally the shovels create buckwalls from the lower bench material, with draglines removing upper bench material and placing it behind the buckwall.

Ripped coal is then loaded by coal loading shovels into 100 ton, bottom dump coal haulers and taken to the coal preparation plant.

Reclamation efforts at this mine have been very successful with their technique of promoting plant growth. Due to poor topsoil composition and prior to OSM's four foot of topsoil regulations, this mine concluded through greenhouse studies that a mixture of topsoil and graded cast over burden produced as good and more often better soil composition. It also achieved a higher percent (in terms of coverage) per acre than without the mixture. As a result of these studies, the mine is now seeking variances to these topsoil regulations. Test results of reclaimed land revealed that this technique of topsoil handling did not change its rock-free characteristic. The total tonnage mined per year is approximately 675,700 tons with an aver age of 180 acres being reclaimed per year.

TABLE A-3

CASE HISTORY #3
UNIT OPERATIONS COST

Topsoil Removal and Reclamation

Equipment & Materials		Cost/Year
2 Bulldozers (D 8)		$ 74,500
4 Scrapers (637 Cat)		277,000
Fuel		
Bulldozers ($5.82/hr. x 1,848 hrs./yr.)		$ 10,800
Scrapers ($8.06/hr. x 1,848 hrs./yr.)		14,900
Seed & Fertilizer		
(Aerial — Contracted Out @ $62.00/Ac. x 180 Ac.)		$ 11,200
Labor and Operator Cost		
Bulldozer Operators (2)		$ 34,600
Scraper Operators (4)		69,200
Laborers (4)		59,900
	Subtotal =	$ 552,000
Auxiliary Operations		
Strip License and Reclamation Fee		$ 369,000
Miscellaneous Equipment, Overhead and Supervision (552,000 x .15)		82,000
	Total Unit Cost =	$1,000,000
	Cost/Acre =	$ 5,570
	Cost/Ton =	$ 1.48

CASE HISTORY MINE #4

General Mining Description

Located in the Raton coalfield of northeastern New Mexico, Mine #4 lies at the foothills of the Rocky Mountains on the western edge of the Great Plains. Semiarid climatic conditions are prevalent in this area due to the influence of the Rocky Mountain Range; the area currently under permit for mining is one of moderate to steeply sloping hills with light forest and sparse vegetative groundcover.

The York seam is extracted from an underground drift mine and there are two relatively new surface mine pits mining metallurgical coal. Coal characteristics are: 14,000 BTU; 7.5% ash; 0.5% sulfur; and fixed carbon 38%. The York seam at this site is fairly flat-lying with very few undulations and/or partings. This mine averages 321,000 tons per year.

To remove coal from the surface pits, a contour mining method is used with an average of 70 feet of consolidated material and thinly bedded, friable shales, with 6 to 8 inches of topsoil. Pit #1 is located on a moderate sloping hill employing a D-9 bulldozer, and two 28 cubic yard scrapers for topsoil removal and stockpiling. Once the bench work, drilling and blasting has concluded, a 14 cubic yard dragline removes 70 feet of overburden casting it to the previous mined-out cut. The coal is loaded into 25 ton coal haulers and transported to their preparation plant for processing.

Reclamation begins with the regrading of the spoil material by a D-9 dozer which also serves to compact the material for stability. Scrapers then redistribute the topsoil material, followed by revegetation. This relatively new surface mine has not reached full stripping potential and approximately 30 acres have been reclaimed to date.

TABLE A-4

CASE HISTORY #4
UNIT OPERATIONS COST

Topsoil Removal and Reclamation

Equipment & Materials		Cost/Year
1 Bulldozer		$ 93,300
2 Scrapers		207,000
1 Hydroseeder & Tractor		4,000
1 Mulcher		2,000
Fuel		
1 Bulldozer ($7.95/hr. x 1,920 hrs./yr.)		$ 15,300
2 Scrapers ($8.06/hr. x 1,920 hrs./yr.)		15,500
1 Hydroseeder & Tractor ($1.30/hr. x 1,920 hrs./yr.)		2,500
Seed (30 ac. @ 50 lbs./ac. x $0.70/lb.)		1,000
Fertilizer and Mulch (30 ac. @ 1,000 lbs./ac. x (30 ac. @ 1,000 lbs./ac. x $0.04/lb.)		1,200
Labor and Operator Cost		
Bulldozer Operator		$ 18,000
Scraper Operators		36,000
Revegetation Crew (4)		62,200
	Subtotal =	$458,000
Auxiliary Operations		
Strip License and Reclamation Fee		$ 2,300
Miscellaneous Equipment, Overhead and Supervision (457,700 x .15)		$ 68,700
	Total Unit Cost =	$529,000
	Cost/Acre =	$ 17,600
	Cost/Ton =	$ 1.65

CASE HISTORY MINE #5

General Mining Description

Mine #5 is located in Ohio, an area characterized by gently rolling hills, pasturelands and moderately steep mountainous areas, with numerous small streams. Mine #5 exclusively mines the Pittsburgh coal seam, with average thickness of 36 inches. Mine #5 averages 102,000 tons of coal mined per year. This seam dips gently to the southeast with minor undulations. The coal quality at this site averages 3-4% sulfur; 10-15% ash (overall) and a BTU of 10,500, with the principle application being steam coal.

The mining method employed at Mine #5 is a variation of the modified box cut contour operation, commencing with clearing and grubbing of all trees, scrubs and brush. The variation in this mining plan are the methods used for topsoil removal. Topsoil material is no longer stored on the downslope side. Instead, it is stored in a predetermined storage area until replacement. Bulldozers construct drill benches to allow for 15 x 15 foot patterns to be drilled for blasting. After blasting, dozers push overburden material down to front end loaders to be hauled to the backstack area by 50 ton rock trucks. Reclamation dozers grade the backstack area to eliminate the highwall and bury oversize boulders. This backstack surface is scarified by bulldozers backblading before the topsoil is replaced. Scrapers then proceed to replace the 6 inches of topsoil material for final reclamation. Rock rakes towed by farm tractors are used to windrow larger rocks in the topsoil. A rock picker, also towed by a farm tractor, is used to remove oversize rock from the topsoil and stockpile them for removal. Since these rocks that are removed are generally small in diameter (< 6 inches), they are used to line their diversion and sedimentation ditches. Reseeding of the 50 acre site is accomplished with a drill seeder for gentle slope areas and a hydroseeder and tractor for steeper slopes.

TABLE A-5

CASE HISTORY #5
UNIT OPERATIONS COST

Topsoil Removal and Reclamation

Equipment & Materials		Cost/Year
2 Bulldozers (D-9)		$ 15,600
2 Scrapers (637 Cat)		17,200
2 Farm Tractors (IH 484)		300
1 Drill Seeder (IH 510)		200
1 Amour Windrower		300
1 Amour Rock Picker		200
Fuel		
Bulldozers ($7.95/hr. x 160 hrs./yr.)		$ 2,500
Scrapers ($8.06/hr. x 160 hrs./yr.)		2,600
Tractors ($2.05/hr. x 160 hrs./yr.)		700
Seed (50 ac. @ 35 lbs./ac. x $0.69/lb.)		1,200
Fertilizer (50 ac. @ 1,000 lbs./ac. x $0.037/lb.)		1,900
Labor and Operator Cost		
Bulldozer Operators (2)		$ 23,900
Scraper Operators (2)		23,900
Utility Equipment Operators (2)		20,800
	Subtotal	$111,000
Auxiliary Operations		
Strip License and Reclamation Fee		$ 25,000
Miscellaneous Equipment, Overhead and Supervision (111,300 x .15)		16,700
	Total Unit Cost =	$153,000
	Cost/Acre =	$ 3,060
	Cost/Ton =	$ 1.50

CASE HISTORY MINE #6

General Mining Description

Located in the southwestern coalfields of Virginia, Mine #6 has typically steep hilled, densely forested and stream dissected terrain which is very characteristic of much of Appalachia. Climatic conditions at this site range from 45°F to 50°F average temperatures and the average annual rainfall is 50 inches.

This multi-seam mountaintop operation extracts 140,000 tons per year of the Upper and Lower Banner seams. Coal thicknesses for both these seams are averaging 5 feet on this site. Coal quality for these seams range from 2-3% moisture, .6-1.1% sulfur, 5.3-8% ash and 13,500-14,700 BTU. Its primary application is for both the domestic and steam markets. Generalized overburden characteristics in the undisturbed area of the mine consist of approximately 50 feet of shale and sandstone, and 15-20 feet of blue slate above the Upper Banner seam. Below this seam is another 30-40 foot band of reddish gray sandstone with 2-10 feet of blue slate above the Lower Banner or (big fork) seam.

Mine #6 has been in operation since the early 1940's. Early mining methods at this site were contour stripping utilizing the shoot and shove method of overburden removal, thereby leaving a 100-200 foot bench and highwall after mining the Lower Banner seam. Today's mining method of mountaintop removal has taken advantage of this established bench and is now mining the Upper and Lower Banner seams. Blasting of the overburden above the Upper Banner seam directs the motion of the overburden into the previously mined out cut. Finally, rock trucks and front-end loaders haul overburden to the backfill area. After coal removal of the Upper Banner seam, blasting of the overburden above the Lower Banner seam is conducted. The pounds per hole of explosive loading for this overburden is not as heavy as the Upper Banner overburden. Only a desired fragmentation and small movement is necessary to facilitate easier pushing by the bulldozer to the loader.

Coal loading once again is with front end loaders loading company owned 25 ton coal trucks. Coal is transported to their tipple for processing and unit train loading.

Reclamation at this mine is only in the beginning phases of the operation. A large valley fill area for their excess spoil material is being constructed and compacted in four foot lifts. With the lack of uniform topsoil thickness throughout this 100 acre site, topsoil replacement will be accomplished by blending the near surface shales with the available topsoil, to be redistributed by scrapers.

TABLE A-6

CASE HISTORY #6
UNIT OPERATIONS COST

Topsoil Removal and Reclamation

Equipment & Materials		Cost/Year
1 Bulldozer (D9H)		$ 23,300
1 Bulldozer (D8K)		13,400
1 Bulldozer (D5)		4,300
3 - 35 Ton Rock Trucks		39,500
2 - 988B Front-End Loaders		20,000
1 Cat 12G Grader		4,600
1 Hydroseeder & Truck		1,000
Fuel		
Bulldozer (D9H) ($7.95/hr. x 712 hrs./yr.)		$ 5,700
Bulldozer (D8K) ($5.82/hr. x 712 hrs./yr.)		4,100
Bulldozer (D5) ($2.04/hr. x 712 hrs./yr.)		1,500
35 Ton Rock Trucks (3) ($6.64/hr. x 712 hrs./yr.)		14,200
Front-End Loaders (2) ($7.28/hr. x 712 hrs./yr.)		10,400
Graders ($2.86/hr. x 712 hrs./yr.)		2,000
Hydroseeder ($2.02/hr. x 712 hrs./yr.)		1,400
Seed (100 ac. @ 35 lbs./ac. x $0.70/lb.)		2,500
Fertilizer (100 ac. @ 1,000 lbs./ac. x $0.04/lb.)		4,000
Labor and Operator Cost		
Bulldozer Operators		$ 16,000
Truck Drivers		15,200
Loader Operators		11,200
Grader Operator		5,100
Revegetation Equipment Operator		5,100
& Helper		4,900
	Subtotal =	$209,000
Auxiliary Operations		
Strip License and Reclamation Fee		$ 81,200
Miscellaneous Equipment, Overhead and Supervision (209,400 x .15)		31,400
	Total Unit Cost	$322,000
	Cost/Acre =	$ 3,220
	Cost/Ton	$ 2.31

CASE HISTORY MINE #7

General Mining Description

Mine #7 is an operation located in southwest Virginia that recovers approximately 135,000 tons of steam grade coal per year from two seams (Upper & Lower Banner at five foot thickness). The mining method employed at the site is the conventional contour haulback with trucks and front-end loaders. Climatic conditions and coal quality are the same as described in Case History Mine #6. Clearing and grubbing of trees that have any economic value are cut and sold to a local sawmill. Other vegetative material is pushed by bulldozers to be burned or to be used as filter barriers below the outcrop to control water runoff.

Overburden encountered has been relatively hard and consolidated, as a result of this condition, drill benches have proven very difficult to construct. Often two drilling and blasting sets are required just to establist the drill bench for the additional 30 to 40 feet of overburden above the top seam. The overburden parting between the upper and lower seams also requires heavy blasting. In this case delayed blasting is used to prevent throwing spoil downslope.

Through the use of bulldozers, the blasted overburden material is cut, ripped and pushed to a waiting loader working in the pit which, in turn, loads 35 and 50 ton overburden haulers. These haulers transport the material to the advancing backfill area where a reclamation bulldozer trims and compacts the spoil to keep the backstack area uniform.

After the coal has been exposed, the surface is cleared and brushed prior to breaking and removal by a 7 cubic yard loader. Two or three 40 ton off-road coal haulers carry the coal either two miles to a predetermined stockpile area or five to six miles to the tipple for processing, where it is sold as industrial steam coal.

Past reclamation efforts at this mine have concentrated on backfilling within approximately 30 feet of the highwall or to a level above the upper seam, whichever leaves the least amount of exposed highwall. Backfill is recompacted in lifts by dozers which results in very good stability. Grading is done by back blading and dragging. Final reclamation of this 60 acre site utilizes fertilizer and mulch to stimulate growth of annual and perennial grasses as well as trees.

TABLE A-7

CASE HISTORY #7
UNIT OPERATIONS COST

Topsoil Removal and Reclamation

Equipment & Materials		Cost/Year
1 Bulldozer (D9H)		$ 23,300
1 Bulldozer (D8K)		13,400
1 Bulldozer (D5)		4,300
3 - 35 Ton Rock Trucks		39,500
1 Hydroseeder & Truck		1,000
Fuel		
Bulldozer (D9H) ($7.95/hr. x 712 hrs./yr.)		$ 5,700
Bulldozer (D8K) ($5.82/hr. x 712 hrs./yr.)		4,100
Bulldozer (D5) ($2.04/hr. x 712 hrs./yr.)		1,500
35 Ton Rock Trucks (3) ($6.64/hr. x 712 hrs./yr.)		14,200
Hydroseeder ($2.02/hr. x 712 hrs./yr.)		1,400
Seed (60 ac. @ 35 lbs./ac. x $0.70/lb.)		1,500
Fertilizer (60 ac. @ 1,000 lbs./ac. x $0.04/lb.)		2,400
Labor and Operator Cost		
Bulldozer Operators		$ 16,000
Truck Drivers		15,200
Revegetation Equipment Operator		5,100
& Helper		4,900
	Subtotal =	$158,000
Auxiliary Operations		
Strip License and Reclamation Fee		$ 48,700
Miscellaneous Equipment, Overhead and Supervision (153,000 x .15)		23,000
	Total Unit Cost =	$225,000
	Cost/Acre =	$ 3,750
	Cost/Ton =	$ 1.67

APPENDIX B

TABLE B-1

CASE HISTORY MINE #8
ECONOMIC SUMMARY

Annual Operating Costs		
Manpower	–	$ 2,400,000
Operating Supplies (Conventional)	–	5,850,000
Auxiliary Cost	–	6,764,000
Indirect Cost	–	1,238,000
Fixed Cost	–	587,000
Depreciation	–	3,025,000
Total Annual Operating Cost		19,865,000
Annual Coal Production	–	1,350,000 Tons
Annual Cost Per Ton		$14.71
Discounted Price Per Ton (15%)	–	$18.82

Subtotals and totals are rounded to significant places.

TABLE B-2

EQUIPMENT COST SUMMARY

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost
*Bulldozers	410 H.P.	2	$ 560,000
Scrapers	31 C.Y.	4	1,241,000
Hydroseeder & Tractor	-	1	21,000
			$ 1,822,000
Overburden Stripping			
Air Rotary Drills	6 3/4"	2	$ 1,050,000
Dragline	44 C.Y.	1	7,800,000
Shovel	40 C.Y.	1	7,000,000
Bulldozer	410 H.P.	1	280,000
			$16,130,000
Coal Removal and Loading			
Coal Shovels	12 C.Y.	2	$ 2,400,000
Coal Haulage			
Coal Haul Trucks	100 Ton	6	$ 1,952,000
Exploration			
Drill		1	$ 115,000
*Bulldozer	410 H.P.	1	280,000
			$ 395,000
Maintenance			
Grader	16' Blade	1	$ 112,000
Mechanic's Trucks	-	2	44,000
Welder's Truck	—	1	14,000
Fuel Truck	3900 Gal.	1	30,000
Lube Truck	-	1	10,000
Oil Truck	—	1	30,000
Explosive Trucks	-	2	48,000
Water Truck	3900 Gal.	1	30,000
			$ 318,000

TABLE B-2 (Cont'd.)

EQUIPMENT COST SUMMARY

Administrative	Capacity	Quantity	Total Cost
Pickup Trucks		6	$ 42,000
Supervisory Pickup Trucks	--	6	$ 42,000
			$ 84,000
		Total Equipment Cost	$23,100,000

TABLE B-3

MANNING TABLE

Topsoil Removal and Reclamation	UMW Grade	Total	Cost Per Year
*Bulldozer Operators	5	2	$ 51,700
Scraper Operators	5	8	206,600
Revegetation Equipment Operator	3	1	23,300
& Helper	1	1	22,400
			$ 304,000
Overburden Stripping			
Drillers	3	6	$ 139,800
Driller's Helpers	2	6	135,500
Dragline Operator	5	3	77,500
Shovel Operators	5	3	77,500
Bulldozer Operators	5	3	77,500
Shooters	3	2	46,600
Shooter's Helpers	2	2	45,200
Oilers	4	3	72,600
			$ 672,200
Coal Removal and Loading			
Shovel Operators	5	4	$ 103,400
Coal Haulage			
Truck Drivers	1	12	$ 268,500
Exploration			
Driller	3	1	$ 23,300
Driller's Helper	3	1	23,300
*Bulldozer Operator	5	1	25,800
			$ 72,400

TABLE B-3 (Cont'd.)

MANNING TABLE

Maintenance	UMW Grade	Total	Cost Per Year
Grader Operators	3	3	$ 69,900
Mechanics	4	3	72,600
Mechanic's Helpers	2	3	67,700
Welders	4	3	72,600
Welder's Helpers	2	3	67,700
Electricians	4	3	72,600
Electrician's Helpers	3	3	69,900
Truck Drivers	1	9	89,500
Laborers	1	6	134,200
			$ 716,700
		Total Labor	$2,137,000

Administrative		Total	Cost Per Year
President		1	$ 40,000
Vice-President		1	35,000
Superintendent		1	30,000
Safety Officer		1	25,000
Engineer		1	25,000
Foremen		3	66,000
Accountant		1	15,000
Secretaries		3	27,000
		Total Supervision =	$ 263,000
		Total Labor & Supervision =	$2,400,000

TABLE B-4

TOTAL ESTIMATED CAPITAL REQUIREMENTS

Exploration, Power Facilities, Site Preparation, Buildings and Roads		$ 1,200,000
Water Treatment Facilities		20,000
Mining Equipment		23,101,000
	Total Direct =	$24,321,000
Field Indirect (2% of Total Direct)		$ 486,000
Engineering		150,000
Overhead and Administration		1,220,000
	Subtotal =	$26,177,000
Contingency (10% of $26,200,000)		$ 2,618,000
	Subtotal =	$28,795,000
Fee (2% of $28,800,000)		$ 576,000
	Total Mine Cost (Base Insurance Tax) =	$29,371,000
Interest During Construction (5% of $29,400,000)		1,470,000
Working Capital		2,730,000
	Total =	$33,570,000

ESTIMATED WORKING CAPITAL

Direct Labor, 3 months		$ 600,000
Payroll Overhead, 3 months		210,000
Operating Supplies, 3 months		1,463,000
Indirect Costs, 3 months		310,000
Fixed Costs, 0.5% of Insurance Base		147,000
	Total	$ 2,730,000

TABLE B-5

ESTIMATED ANNUAL OPERATING COSTS

Direct Cost		
Labor		$ 2,137,000
Supervision		263,000
	Subtotal =	$ 2,400,000
Operating Supplies		
Fuel		$ 1,700,000
Lubricants		271,000
Explosives		1,424,000
Leased Equipment		--
Parts, Materials and Miscellaneous		2,460,000
	Subtotal =	$ 5,855,000
Auxiliary Cost		
Royalty		$ 2,700,000
Power		306,000
Communications		10,000
Union Welfare		2,700,000
Payroll Overhead		840,000
Health and Safety		19,000
Contract Coal Haulage		--
Strip License and Reclamation Fee		190,000
	Subtotal =	$ 6,765,000
	Total Direct Cost =	$15,015,000
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies		$ 1,238,000
Fixed Cost: Taxes and Insurance, 2% of Mine Cost		$ 587,000
Depreciation		$ 3,025,000
	Total Operating Cost =	$19,865,000

TABLE B-6

DEPRECIATION SCHEDULE

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
Dragline	1	20	$ 390,000
Stripping Shovel	1	20	350,000
Coal Shovel	2	10	240,000
Dozers	4	3	373,000
Scrapers	4	3	414,000
Coal Haulers	6	5	390,000
Drills (6 3/4")	2	5	210,000
Grader	1	8	14,000
Mechanic's Trucks	2	3	15,000
Welder's Truck	1	3	5,000
Water Truck	1	3	10,000
Fuel Truck	1	3	10,000
Lube Truck	1	3	1,000
Oil Truck	1	3	10,000
Explosive Trucks	2	3	16,000
Pickup Trucks	12	3	28,000
Drill (3")	1	5	23,000
Hydroseeder & Tractor	1	5	4,000
Exploration, Power Facilities, Site Preparation, Buildings and Roads	-	20	$ 60,000
Water Treatment Facilities Depreciation	--	20	1,000
Depreciation: Field Indirect, Engineering, Overhead and Administration, Contingency, Fee, and Interest During Construction	—	20	326,000
Interim Equipment Cost			135,000
		Total =	$3,025,000

TABLE B-7
CASH FLOW ANALYSIS

Year	Capital Investment	Cash Flow	Present Worth Factor at 15 Percent	Present Worth Capital Investment at 15 Percent	Present Worth Cash Flow Value at 15 Percent
0	33,571,000	33,571,000	1 0000	33,571,000	33,571,000
1	135,000	7,047,000	8696	117,000	6,128,000
2	135,000	7,047,000	7561	102,000	5,328,000
3	2,786,000	4,396,000	6575	1,832,000	2,890,000
4	135,000	7,047,000	5718	77,000	4,029,000
5	3,273,000	3,909,000	4972	1,627,000	1,944,000
6	2,786,000	4,396,000	4323	1,204,000	1,891,000
7	135,000	7,047,000	3759	51,000	2,649,000
8	247,000	6,935,000	3269	81,000	2,267,000
9	2,786,000	4,396,000	2843	792,000	1,250,000
10	12,673,000	5,491,000	2472	3,133,000	1,357,000
11	135,000	7,047,000	2149	29,000	1,513,000
12	2,786,000	4,396,000	1869	521,000	822,000
13	135,000	7,047,000	1625	22,000	1,145,000
14	135,000	7,047,000	1414	19,000	996,000
15	13,724,000	-6,542,000	1229	1,687,000	-804,000
16	247,000	6,935,000	1068	26,000	741,000
17	135,000	7,047,000	0930	13,000	655,000
18	2,786,000	4,396,000	0808	225,000	355,000
19	135,000	7,047,000	0702	9,000	495,000
20	3,025,000	10,207,000	0611	184,000	624,000
			Total	44,954,000	0

R = $44,954,000 ÷ 6.2593 — $ 7,182,000

Less depreciation — $ 3,025,000
Depletion + net profit — $ 4,157,000

Gross Profit = 1/0.75 × $4,157,000 — $ 5,543,000
Sales = $19,864,000 + $5,543,000 — $ 25,407,000

Gross profit	$ 5,543,000
Depletion (10% of sales)	$ 2,772,000
Taxable income	$ 2,771,000
Federal Income Tax (at 50%)	$ 1,385,000
Net profit	$ 1,385,000

Annual Cash Flow = $1,385,000 + $3,025,000 + $2,772,000 = $7,182,000
Selling Price Per Ton = $25,407,000 ÷ 1,350,000 Tons — $18.82

TABLE B-8

UNIT OPERATION COSTS
TOPSOIL REMOVAL AND RECLAMATION

Equipment and Materials		Cost/Year
4 - Scrapers (CAT 31 cy)		$ 414,000
2 - Bulldozers (CAT D 9)		187,000
1 - Hydroseeder and Tractor		4,000
Fuel		
4 - Scrapers (31 cy) ($8.06/hr. x 22,080 hrs./yr.)		178,000
2 - Bulldozers (D-9) ($7.95/hr. x 11,044 hrs./yr.)		87,800
1 - Hydroseeder and Tractor ($3.80/hr. x 2,760 hrs./yr.)		10,500
Seed		
190 ac. at 50 lbs./ac. x $0.69/lb.		6,600
Fertilizer		
190 ac. at 1,000 lbs./ac. x $0.037/lb.		7,000
Labor and Operator Costs		
Scraper Operators		206,600
Bulldozer Operator		51,700
Revegetation Equipment Operator		23,300
and Helper		22,400
	Subtotal	$1,198,900
Auxiliary Operations		
Strip License and Reclamation Fee		190,000
Miscellaneous Equipment, Overhead and Supervision (12,623,000 x .17)		2,144,000
	Total	$3,533,000

Subtotals and totals are rounded to significant places.

TABLE B-9

UNIT OPERATION COSTS
OVERBURDEN STRIPPING

		Cost/Year
Equipment and Materials		
2 - Air Rotary Drill (6 3/4")		$ 210,000
1 - Dragline (B.E. 44 cy)		390,000
1 - Shovel (B.E. 40 cy)		350,000
1 - Bulldozer (D-9)		93,300
Fuel		
Air Rotary Drill ($7.61/hr. x 16,560 hrs./yr.)		126,000
Dragline (Electric Power)		256,000
Shovel (Electric Power)		256,000
Bulldozer ($7.95/hr. x 8,280)		65,800
Explosives Cost		1,424,000
Labor and Operator Costs		
Drillers		139,800
Driller's Helper		135,800
Dragline Operator		77,500
Shovel Operator		77,500
Bulldozer Operator		77,500
Shooter		46,600
Shooter's Helper		45,200
Oilers		72,600
	Subtotal	$ 3,843,600
Auxiliary Operations		
Miscellaneous Equipment, Overhead and Supervision (12,623,000 x .60)		7,319,300
	Total	$11,163,000

TABLE B-10

UNIT OPERATION COSTS
COAL REMOVAL AND LOADING

		Cost/Year
Equipment and Materials		
2 Shovels		$ 240,000
Fuel		
2 Shovels (Electric Power)		93,800
Labor and Operation Costs		
Shovel Operators		103,400
	Subtotal	$ 437,200
Auxiliary Operations		
Miscellaneous Equipment, Overhead and Supervision (12,623,000 x .06)		881,600
	Total	$ 1,319,000

TABLE B-11

UNIT OPERATION COSTS
COAL HAULAGE

Equipment and Materials		Cost/Year
6 Coal Haul Trucks (100 ton)		$ 390,000
Fuel		
Coal Haul Trucks ($9.60/hr. x 33,120 hrs./yr.)		318,000
Labor and Operations Cost		
10 Truck Drivers		268,500
	Subtotal	$ 976,500
Auxiliary Operations		
Miscellaneous Equipment, Overhead and Supervision (12,623,000 x .14)		$1,891,500
	Total	2,868,000

TABLE B-12

UNIT OPERATION COSTS
EXPLORATION

Equipment and Materials		Cost/Year
1 - Drill		$ 21,000
1 - Dozer		93,300
Fuel		
Drill ($4.08/hr. x 2,760 hrs./yr.)		11,300
Dozer ($7.95/hr. x 2,760 hrs./yr.)		21,900
Labor and Operator Costs		
Driller		23,300
Driller's Helper		22,300
Dozer Operator		25,800
	Subtotal	$218,900
Auxiliary Operations		
Miscellaneous Equipment, Overhead and Supervision (12,623,000 x .03)		376,700
	Total	$596,000

TABLE B-13

UNIT OPERATION COSTS
MAINTENANCE AND SUPERVISORY OPERATIONS

Equipment and Material

1 - Grader		$ 14,000
2 - Mechanic Trucks		15,000
1 - Welder Truck		5,000
1 - Fuel Truck		10,000
1 - Oil Truck		10,000
2 - Explosive Trucks		16,000
1 - Water Truck		10,000
1 - Lube Truck		1,000
12 - Pick-ups		28,000
	Subtotal	$ 109,000

Fuel

Grader ($5.30/hr. x 2,760 hrs./yr.)		14,600
Mechanic Truck ($3.80/hr. x 5,520 hrs./yr.)		21,000
Welder Truck ($3.80/hr. x 5,520 hrs./yr.)		21,000
Fuel Truck ($5.18/hr. x 2,760 hrs./yr.)		14,300
Oil Truck ($5.18/hr. x 5,520 hrs./yr.)		28,600
Explosive Truck ($3.80/hr. x 12,420 hrs./yr.)		47,200
Water Truck ($5.18/hr. x 2,760 hrs./yr.)		14,300
Lube Truck ($5.18/hr. x 2,760 hrs./yr.)		14,300
Pick-up ($2.99/hr. x 33,120 hrs./yr.)		99,000
Lubricants		271,000
Parts, Materials, Miscellaneous		2,455,000
	Subtotal	$3,000,000

Labor and Supervisory Personnel

Grader Operator		69,900
Mechanics		72,600
Mechanic's Helpers		67,700
Welder		72,600
Welder's Helpers		67,700
Electricians		72,600
Electrician's Helpers		69,900
Truck Drivers		89,500
Laborers		134,000
Supervisory Personnel		263,000
	Subtotal	$ 980,000

TABLE B-13 (Cont'd.)

UNIT OPERATION COSTS
MAINTENANCE AND SUPERVISORY OPERATIONS

Auxilliary Costs

Communications		10,000
Union Welfare		2,700,000
Payroll Overhead		840,000
Health and Safety		18,000
Royalty		2,700,000
Indirect Costs		1,238,000
Fixed Costs		587,000
Interim Equipment Cost		135,000
Power		306,000
	Subtotal	$8,534,000
	Total	$12,623,000

PLANNING AND DEVELOPMENT

Power Facilities, Site Preparation, Buildings and Roads		61,000
Field Indirect		24,300
Engineering		7,500
Overhead and Administration		61,000
Contingency		131,000
Fee		28,800
Interest During Construction		73,500
Working		137,000
	Total	$524,000

TABLE B-14

UNIT OPERATION COSTS SUMMARY

		Cost/Year
Topsoil Removal and Reclamation		$ 3,533,000
Overburden Stripping		11,163,000
Coal Removal and Loading		1,319,000
Coal Haulage		2,868,000
Exploration		596,000
Planning and Development		524,000
	Total	20,003,000

TABLE B-15

CASE HISTORY MINE #9
ECONOMIC SUMMARY

Annual Operating Costs		
Manpower	-	$ 846,000
Operating Supplies (Conventional)	-	1,203,000
Auxiliary Cost	-	996,000
Indirect Cost		307,000
Fixed Cost	-	75,000
Depreciation		726,000
Total Annual Operating Cost	-	4,153,000
Annual Coal Production	-	147,000 Tons
Annual Cost Per Ton	-	$28.25
Discounted Price Per Ton (15%)	-	$33.00

Subtotals and totals are rounded to significant places.

TABLE B-16

EQUIPMENT COST SUMMARY

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost
Bulldozer	524 H.P.	1	$ 320,000
Scraper	30 C.Y.	1	297,000
Hydroseeder & Tractor	--	1	21,000
			$ 638,000
Overburden Stripping			
Air Rotary Drill	$6\frac{1}{2}$"	1	$ 200,000
Bulldozers w/Rippers	410 H.P.	2	560,000
Dragline	9 C.Y.	1	900,000
Explosives Truck	--	1	14,000
			$1,674,000
Coal Removal and Loading			
Front-End Loader	7 C.Y.	1	$ 212,000
Coal Haulage			
Contracted Out @ $1.75/Ton			
Exploration			
Contracted Out			
Maintenance			
Grader	--	1	$ 102,000
Maintenance Truck	--	1	20,000
Parts Truck	--	1	11,000
			$ 133,000
Administrative			
Pickup Trucks	--	5	Leased
	Total Cost of Equipment		$2,657,000

TABLE B-17

MANNING TABLE

Topsoil Removal and Reclamation	Total		Cost Per Year
Bulldozer Operator	1		$ 35,600
Scraper	1		35,600
Revegetation Equipment Operator	1		16,900
& Helper	1		16,200
			$104,300
Overburden Stripping			
Drillers	2		$ 64,200
Drillers' Helpers	2		61,800
Shooters	2		64,200
Shooters' Helpers	2		61,800
Bulldozer Operators	2		71,300
Dragline Operators	3		71,300
Dragline Oilers	3		66,800
			$461,400
Coal Removal and Loading			
Loader Operator	1		$ 18,700
Coal Haulage			
Contracted Out @ $1.75/Ton			
Exploration			
Contracted Out			
Maintenance			
Grader Operator	1		$ 32,100
Mechanic	1		33,400
Mechanic's Helper	1		32,100
Welder	1		33,400
Laborer	1		30,900
		Subtotal	= $161,900
		Total Labor	= $746,000

TABLE B-17 (Cont'd.)

MANNING TABLE

Administrative	Total	Cost Per Year
President	1	$ 8,000 (20%)
Superintendent	1	9,000 (30%)
Foremen	2	50,000 (100%)
Safety Officer	1	16,000 (60%)
Engineer	1	8,000 (30%)
Secretary	1	9,000 (100%)
	Total Supervision	$100,000
	Total Labor & Supervision	$846,000

TABLE B-18

TOTAL ESTIMATED CAPITAL REQUIREMENTS

Exploration, Treatment Facilities, Site Preparation, Buildings, and Roads			$ 200,000
Mining Equipment			2,657,000
	Total Direct	=	$2,857,000
Field Indirect (2% of Total Direct)			$ 57,000
Engineering			15,000
Overhead and Administration			423,000
	Subtotal	=	$3,352,000
Contingency (10% of $3,352,000)			335,000
	Subtotal	=	$3,687,000
Fee (2% of $3,687,000)			74,000
	Total Mine Cost (Base Insurance Tax)	=	$3,761,000
Interest During Construction (5% of $3,761,000)		=	188,000
Working Capital			688,000
	Total	=	$4,637,000

ESTIMATED WORKING CAPITAL

Leased Equipment, 3 months			$ 5,000
Direct Labor, 3 months			212,000
Payroll Overhead, 3 months			74,000
Operating Supplies, 3 months			301,000
Indirect Costs, 3 months			77,000
Fixed Costs, 0.5% of Insurance Base			19,000
	Total	=	$ 688,000

TABLE B-19
ESTIMATED ANNUAL OPERATING COSTS

Direct Cost		
Labor		$ 746,000
Supervision		100,000
	Subtotal =	$ 846,000
Operating Supplies		
Fuel		$ 282,000
Lubricants		95,000
Explosives		465,000
Leased Equipment		20,000
Parts, Materials and Miscellaneous		341,000
	Subtotal =	$1,203,000
Auxiliary Cost		
Royalty		$ 147,000
Power		12,000
Communications		10,000
Union Welfare		257,000
Payroll Overhead		296,000
Health and Safety		8,000
Contract Coal Haulage		257,000
Coal Preparation Plan Seed and Fertilizer		1,000
Strip License and Reclamation Fee		8,000
	Subtotal =	$ 996,000
	Total Direct Cost =	$3,045,000
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies		$ 307,000
Fixed Cost: Taxes and Insurance, 2% of Mine Cost		75,000
Depreciation		726,000
	Total Operating Cost =	$4,153,000

TABLE B-20

DEPRECIATION SCHEDULE

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
Bulldozer	1	3	$106,700
Hydroseeder & Tractor	1	5	4,200
Air Rotary Drill	1	5	40,000
Scraper	1	3	99,000
Bulldozers w/Rippers	2	3	186,700
Dragline	1	10	90,000
Explosives Truck	1	3	4,700
Front-End Loader	1	3	70,700
Grader	1	3	34,000
Maintenance Truck	1	3	6,700
Parts Truck	1	3	3,700
Exploration, Treatment Facilities, Site Preparation, Buildings and Roads	--	20	$ 10,000
Depreciation: Field Indirect, Engineering, Overhead and Administration, Contingency, Fee, and Interest During Construction	--	20	$ 54,600
Interim Equipment Cost	--	--	$ 15,000
		Total	$726,000

TABLE B-21
CASH FLOW ANALYSIS

Year	Capital Investment	Cash Flow	Present Worth Factor At 15 Percent	Present Worth Capital Investment At 15 Percent	Present Worth Cash Flow Value At 15 Percent
0	$4,637,000	$4,637,000	1 0000	$4,637,000	$4,637,000
1	15,000	1,233,000	8696	13,000	1,072,000
2	15,000	1,233,000	7561	11,000	932,000
3	1,551,000	- 303,000	6575	1,020,000	199,000
4	15,000	1,233,000	.5718	9,000	705,000
5	236,000	1,012,000	4972	117,000	503,000
6	1,551,000	303,000	4323	670,000	131,000
7	15,000	1,233,000	3759	6,000	463,000
8	15,000	1,233,000	3269	5,000	403,000
9	1,551,000	303,000	2843	441,000	86,000
10	1,136,000	112,000	2472	281,000	28,000
11	15,000	1,233,000	2149	3,000	265,000
12	1,551,000	303,000	1869	290,000	57,000
13	15,000	1,233,000	1625	2,000	200,000
14	15,000	1,233,000	1414	2,000	174,000
15	1,772,000	524,000	1229	218,000	64,000
16	15,000	1,233,000	1068	2,000	132,000
17	15,000	1,233,000	0930	1,000	114,000
18	1,551,000	303,000	0808	125,000	24,000
19	15,000	1,233,000	0702	1,000	86,000
20	726,000	1,974,000	0611	44,000	121,000
			TOTAL	$7,810,000	0

R $7,810,000 ÷ 6.2593	$1,248,000
Less depreciation	$ 726,000
Depletion + net profit	$ 522,000
Gross profit 1/0.75 × $522,000	$ 696,000
Sales $4,152,000 + $696,000	$4,848,000
Gross Profit	$ 696,000
Depletion (10% of sales)	$ - 348,000
Taxable Income	$ 348,000
Federal Income Tax (at 50%)	$ 174,000
Net Profit	$ 174,000
Annual Cash Flow $174,000 + $348,000 + $726,000	$1,248,000
Selling Price Per Ton $4,848,000 147,000 Tons	$33.00

TABLE B-22

UNIT OPERATION COSTS
TOPSOIL REMOVAL AND RECLAMATION

Equipment and Materials		Cost/Year
Bulldozer		$106,700
Scraper		99,000
Hydroseeder and Tractor		4,200
Fuel		
Bulldozer ($7.95/hr. x 3,450 hrs./yr.)		27,400
Scraper ($8.06/hr. x 3,450 hrs./yr.)		27,800
Hydroseeder and Tractor ($0.78/hr. x 2,000 hrs./yr.)		1,560
Seed		
30 ac. @ 40 lbs./ac. x $0.69/lb.		1,000
Fertilizer		
30 ac. @ 1,000 lbs./ac. x $0.037/lb.		1,100
Explosives		
Labor		
Bulldozer Operator		35,600
Scraper Operator		35,600
Revegetation Equipment Operator		16,900
and Helper		16,200
	Subtotal	$373,060
Auxiliary Operations		
Strip License and Reclamation Fee		8,000
Miscellaneous Equipment, Overhead and Supervision ($1,928,000 x .20)		386,000
	Subtotal	$394,000
	Total =	$767,000

Subtotals and totals are rounded to significant places.

TABLE B-23

UNIT OPERATION COSTS
OVERBURDEN STRIPPING

Equipment and Materials		Cost/Year
Air Rotary Drill		$ 40,000
Bulldozer with Ripper		186,700
Dragline		90,000
Explosives Truck		4,700
Fuel		
Air Rotary Drill ($2.75/hr. x 6,900 hrs./yr.)		19,000
Bulldozer with Ripper ($7.95/hr. x 6,900 hrs./yr.)		54,900
Dragline ($12.26/hr. x 6,900 hrs./yr.)		84,600
Explosives Truck ($1.08/hr. x 6,900 hrs./yr.)		7,500
Explosives		465,000
Labor		
Drillers		64,200
Drillers Helpers		61,800
Bulldozer Operators		71,300
Dragline Operators		71,300
Dragline Oilers		66,800
Shooters		64,200
Shooters Helpers		61,800
	Subtotal	$1,414,000
Auxiliary Operations		
Miscellaneous Equipment, Overhead and Supervision ($1,928,000 x .75)		1,446,000
	Total	$2,860,000

TABLE B-24

UNIT OPERATION COSTS
COAL REMOVAL AND LOADING

Equipment and Materials		Cost/Year
Front-end Loader		$ 70,700
Fuel		
Front-end Loader ($7 28/hr. x 2,000 hrs./yr.)		14,600
Labor		
Front end Loader Operator		18,700
	Subtotal	$104,000
Auxiliary Operations		
Miscellaneous Equipment, Overhead and Supervision ($1,928,000 x .05)		96,400
	Total	$200,000

COAL HAULAGE

Contracted out @ $1.75/ton for 147,000 tons	$257,000

EXPLORATION

Contracted out @ $3.00/foot for 1,200 feet	$ 3,600

TABLE B-25

UNIT OPERATION COSTS
MAINTENANCE AND SUPERVISORY OPERATIONS

Equipment and Materials		
Grader		$ 34,000
Maintenance Truck		6,700
Parts Truck		3,700
Pick-up Truck		20,000
	Subtotal	$ 64,400
Fuel		
Grader ($2.95/hr. x 3,450 hrs./yr.)		10,200
Maintenance Truck ($1.64/hr. x 3,450 hrs./yr.)		5,700
Parts Truck ($1.04/hr. x 3,450 hrs./yr.)		3,600
Pick-up Truck ($1.04/hr. x 17,250 hrs./yr.)		18,000
Lubricants		95,000
Parts, Materials and Miscellaneous		341,000
	Subtotal	$ 473,500
Labor and Supervisory Personnel		
Grader Operator		32,000
Mechanic		33,400
Mechanic's Helper		32,100
Welder		33,400
Laborer		30,900
Supervisory Personnel		100,000
	Subtotal	$ 261,800
Auxiliary Costs		
Communications		10,000
Union Welfare		257,000
Payroll Overhead		296,000
Health and Safety		8,000
Royalty		147,000
Indirect Costs		307,000
Fixed Costs		75,000
Interim Equipment Cost		15,000
Power		12,000
Seed Fertilizer		1,000
	Subtotal	$1,128,000
	Total	$1,928,000

TABLE B-26

UNIT OPERATION COSTS
PLANNING AND DEVELOPMENT

		Cost/Year
Treatment Facilities, Site Preparation, Buildings and Roads		$ 10,000
Field Indirects		3,000
Engineering		1,000
Overhead and Administration		21,000
Contingency		17,000
Fee		4,000
Interest During Construction		9,000
Working Capital		34,000
	Total	$ 99,000

SUMMARY

Topsoil Removal and Reclamation		$ 767,000
Overburden Stripping		2,860,000
Coal Haulage		257,000
Coal Removal and Loading		200,000
Exploration		3,600
Planning and Development		99,000
	Total	$4,187,000