

Information Circular 8761

**Preliminary Economics of Mining
a Thick Coal Seam by Dragline,
Shovel-Truck, and Scraper
Mining Systems**

By Michael J. Bertoldi



**UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary
BUREAU OF MINES**

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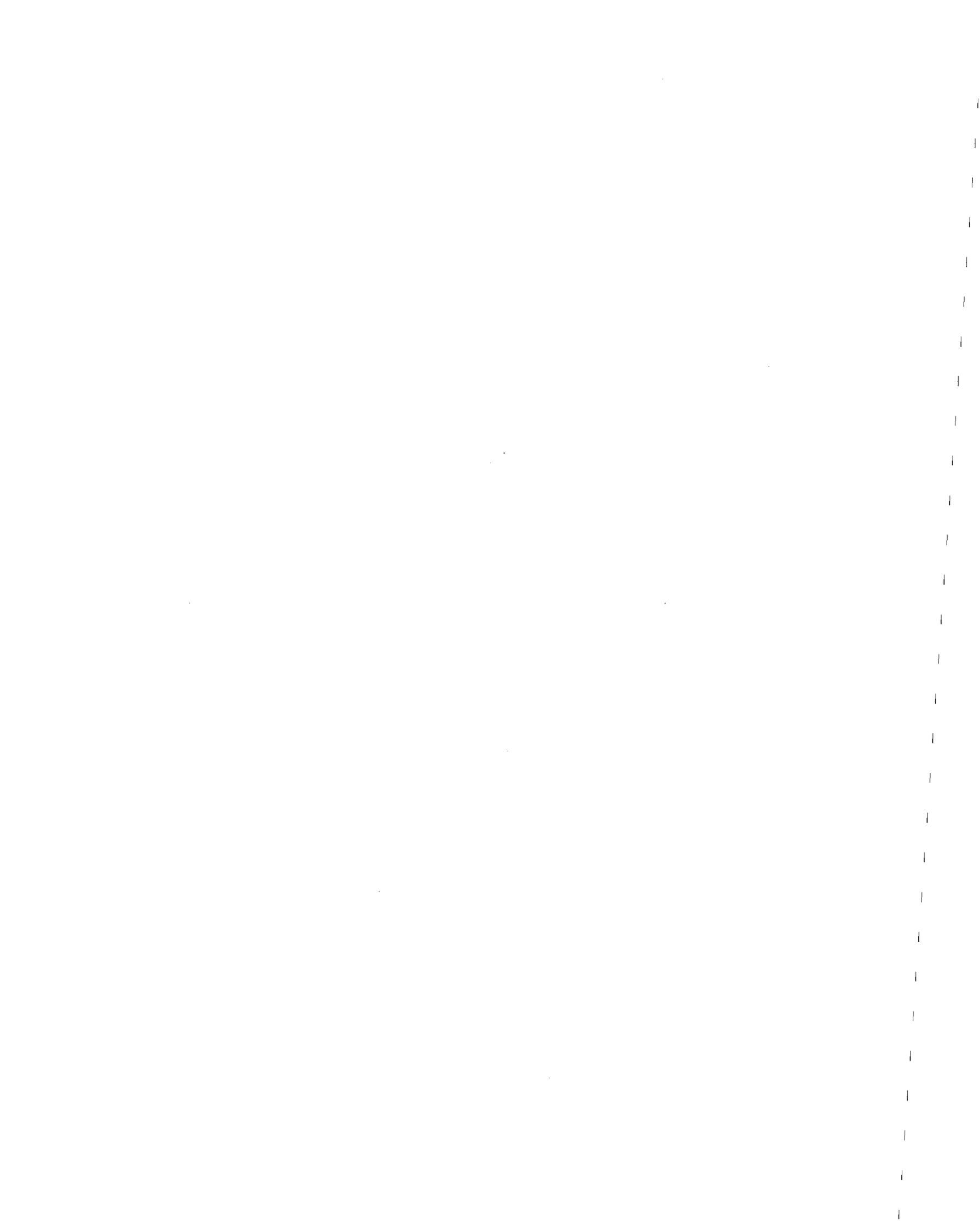
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CONTENTS

	<u>Page</u>
Abstract.....	1
Introduction.....	1
Acknowledgments.....	2
Advantages and disadvantages.....	2
Dragline.....	2
Shovel-truck.....	3
Scraper.....	3
Dragline mining system.....	4
Shovel-truck mining system.....	6
Scraper mining system.....	8
Conclusion.....	9
Bibliography.....	11
Appendix A.--Design parameters.....	13
Appendix B.--Dragline mining system.....	14
Appendix C.--Shovel-truck mining system.....	18
Appendix D.--Scraper mining system.....	22
Appendix E.--Cash flow analysis.....	26

TABLES

B-1. Total estimated capital requirements, dragline mining system.....	14
B-2. Estimated working capital, dragline mining system.....	14
B-3. Capital investment summary, dragline mining system.....	15
B-4. Annual cost of supervisory personnel, dragline mining system.....	16
B-5. Annual cost of hourly personnel, dragline mining system.....	16
B-6. Estimated annual production cost, dragline mining system.....	17
C-1. Total estimated capital requirements, shovel-truck mining system.....	18
C-2. Estimated working capital, shovel-truck mining system.....	18
C-3. Capital investment summary, shovel-truck mining system.....	19
C-4. Annual cost of supervisory personnel, shovel-truck mining system.....	20
C-5. Annual cost of hourly personnel, shovel-truck mining system.....	20
C-6. Estimated annual production cost, shovel-truck mining system.....	21
D-1. Total estimated capital requirements, scraper mining system.....	22
D-2. Estimated working capital, scraper mining system.....	22
D-3. Capital investment summary, scraper mining system.....	23
D-4. Annual cost of supervisory personnel, scraper mining system.....	24
D-5. Annual cost of hourly personnel, scraper mining system.....	24
D-6. Estimated annual production cost, scraper mining system.....	25
E-1. Comparable production costs.....	26
E-2. Cash flow analysis (\$5.24 assumed price).....	27



PRELIMINARY ECONOMICS OF MINING A THICK COAL SEAM
BY DRAGLINE, SHOVEL-TRUCK, AND SCRAPER
MINING SYSTEMS¹

by

Michael J. Bertoldi²

ABSTRACT

The purpose of this Bureau of Mines report is to describe the methods and establish the basic economics for dragline, shovel-truck, and scraper mining systems. An overall view of the techniques of preliminary design and the cost involved is presented. Considerations of equipment selection, emphasizing short-range evaluation of required equipment, and a long-range evaluation are considered at a constant production rate over the life of a hypothetical mine.

Separate cost analyses for each system were based on 1977 equipment prices, prevailing wage rates, and associated mining costs. Specific engineering and cost breakdown for such items as access roads, transmission line installation, rail spurs, etc., are beyond the scope of this report.

INTRODUCTION

A total mining system is a composite of many subsystems. Any system originated for an undeveloped property must be evaluated by cost and it must encompass all applicable geologic and mining limitations.

This report evaluates the cost of mining an area by dragline, shovel-truck, and scraper methods. A hypothetical deposit is assumed to contain a single coalbed 50 feet thick, overlain by 70 feet of sandstone, soft shales, and soils. These conditions could be similar to those occurring in the northern Great Plains coal province. Annual production is assumed to be 5,000,000 tons with a mine life of 20 years.

The procedure used in estimating costs is based on methodology developed by the Bureau of Mines Process Evaluation Office, Morgantown, W. Va. (8).³ Each evaluation considers initial exploration, overburden preparation and removal, coal loading, and haulage to a storage point. Coal cleaning facilities are

¹The work described in this report was performed by a component of the Bureau of Mines that was transferred to the Department of Energy on October 1, 1977.

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³Underlined numbers in parentheses refer to items in the bibliography preceding the appendixes.

not included. Equipment prices and wage scales considered were those in effect in January 1977. Costs, other than initial equipment capitalization, were determined for conditions prevalent at similar mining operations in the Western United States. Operating costs were calculated from published data on equipment performance and specifications.

Costs for similar operations for each mine estimate were calculated and applied to all estimates. Explosive consumption was based on separate ratios of explosive per cubic yard of overburden fragmented for each method. Bit consumption was determined on the calculated annual footage to be drilled at each mine and bit life data published by the manufacturers. Detailed cost figures and specific considerations for each of the three systems are listed in the appendices.

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ADVANTAGES AND DISADVANTAGES

The relative advantages of the three systems may include factors such as geology--not reflected in the economic evaluations. Some of the advantages and disadvantages of the systems are listed as follows:

Dragline

Advantages

1. Can handle coarse and various types of material.
2. Low operating and maintenance cost per cubic yard of material.
3. Low operator fatigue.
4. Excellent versatility in multiple seams.
5. Can dig above and below grade.
6. Economical for overburden depths of over 100 feet.
7. Excellent variability under assorted field conditions.
8. Segregation capabilities.
9. Generates little dust.

Disadvantages

1. Lower breakout force than shovels.
2. Small transport distance--may have to rehandle a portion of the material.
3. High initial cost.
4. Dozer usually needed as support.

Shovel-Truck

Advantages

1. Low operating costs and maintenance requirements.
2. Low operator fatigue.
3. Long reach at face.
4. Excellent for close-quarters work.
5. Smooth digging action.
6. Can handle coarse materials.
7. Segregation capabilities are better than dragline methods.

Disadvantages

1. Low mobility.
2. High initial capital requirements.
3. Wheel loader usually needed as support.
4. Limited by steep grades.
5. Trucks generate dust.
6. Higher amount of road construction and maintenance.

Scraper

Advantages

1. Self-loading under some geologic and equipment selections.
2. Excellent traction (all-wheel drive types).

3. Excellent mobility.
4. Excellent maneuverability.
5. Excellent gradability.
6. Downtime has no effect on other units.
7. Can easily blend or segregate materials.
8. Used as support and for flexibility with other stripping methods.
9. Excellent segregation capabilities.

Disadvantages

1. High cost and tractive efforts in consolidated materials.
2. Suited for short to medium haul lengths.
3. Poor gross weight to tire weight ratio.
4. Generates dust.
5. Higher operating and maintenance costs than shovels and draglines.

DRAGLINE MINING SYSTEM

A dragline performs two functions: excavating and conveying. It has a five-element cycle: drag, transport, dump, return, and position. The usual cycle time is approximately 55 to 60 seconds depending on size and conditions.

Draglines, as applied in western stripping operations, usually handle blasted sedimentary rocks to depths of over 100 feet. The dragline is accepted as the machine that can move a cubic yard at lower cost than other methods except for a bucket wheel excavator.

Walking draglines range from 15- to 220-cubic-yard capacity. They are limited to travel on less than 8 to 10 percent slopes, and they average around 0.1 mile per hour walking.

The size depends on the amount of overburden, the required production, and the total coal reserves of the property. Dragline digging action is related to the weight of the bucket during the drag cycle. A dragline will handle various rock types and sizes.

When formulating a preliminary design for a dragline mine, five factors must be determined by handbooks or onsite investigations. These factors are angle of highwall, angle of repose, cut width, swell, and bench height. Pit design also depends upon required production, geologic factors, working area, and equipment limitations. The pit must be of adequate size to attain the

required production accounting for geologic features that affect slope stability, depth and thickness of coal, etc. Working areas must be sized for machine maneuverability, clearances, and safety while maintaining the working capabilities of the equipment.

Dragline methods are highly variable and can range from complicated to simple. Depending on mining and reclamation requirements, mining methods range from split bench one- or two-pass systems and extended benches to simple single-pass systems. In multiple-seam mining, draglines are sometimes used to "chop" interburden which decreases dragline productivity and further complicates the mining system.

Mining methods utilizing draglines are also used in pitching seams. Characteristics of the geology and amount of dip, either dipline (updip), strikeline (along the strike of the coal), or diagonal mining is selected. All possess certain differences of slope stability, highwall stability, and reclamation. Diagonal mining is used in steeper pitched seams than are possible with the other methods.

Dipline mining consists of opening a cut parallel to dip and then mining updip. This possesses the disadvantages of walking the dragline uphill (benches) and erosional problems.

In strikeline mining, the cut opens along strike and progresses parallel to the strike. Strikeline mining offers a high degree of environmental protection because of the better erosional and sedimentation control characteristics. Highwall stability is a major consideration and coal haulage can possess potential problems.

Diagonal mining is a combination of dipline and strikeline. The coal is mined at an angle to strike and dip.

In all three pitching seam methods, floor heave, spoil pile erosion, water quality, and drainage can be major problems. Geology, physiography, and Government regulations determine which mining method is used.

The main production factors that affect dragline performance are deadheading, rehandling, chopping, and keycutting. Deadheading is walking the dragline without excavating. Rehandling of material (moving the same overburden twice) is dependent on boom length, pit width, pit depth, and mining method. Chopping is usually performed on interburden by moving the dragline to the interburden or spoil area. The dragline (on the spoil area) faces the highwall and chops at the interburden. The swing angle is increased and the dragline must work at a lower elevation, increasing hoist and spoiling height. A dragline and dragline bucket are not designed for chopping and efficiency is drastically lowered. Keycutting is the excavation of a trench in the highwall to obtain a competent area to position the dragline.

Pit widths can be highly variable and are dependent on safety, slope stability, and overburden depths. The narrowest practical pit is usually the most economical. It decreases rehandling requirements at curves, entries, and

high cover areas. Dragline cycle times are also reduced, and reclamation is initiated more rapidly. Spoil piles are closer spaced and regrading costs are less in narrow pits.

In most dragline pits, it is common practice to separate the overburden, stripping, and coal loading operations by an unmined portion of coal. This is to prevent interference with coal production during dragline downtime.

The described mining method is a conventional dragline sidecasting system employing a 24-cubic-yard dragline for overburden removal and utilizing two 8-cubic-yard coal loading shovels with eight 85-ton coal haulers for mining the coal in a pit 110 feet wide. Two 85-ton trucks are included as spares.

The shallow soil from the unmined area will be removed and stored prior to overburden removal and distributed to the backfilled area by scraper as mining advances.

Overburden preparation will consist of drilling 10-5/8-inch-diameter holes spaced in a 25- by 25-foot pattern. Blasting to loosen the overburden will be accomplished with ammonium nitrate-fuel oil mixture. Twenty-five-grain detonating cord is used as the trunkline, 50-grain cord is used as the downlines, and one booster primer per hole is used for ignition. Progressive timing and buffer shooting are assumed to be used. A 300-hp dozer will be used to level the bench before drilling commences, and a rotary-electric drill with 125,000 pounds of available thrust will be used.

Coal preparation will consist of drilling 7-7/8-inch diameter holes in a 25- by 25-foot pattern. Ammonium nitrate-fuel oil mixtures will be used as the blasting agent with progressive timing and similar priming and detonating practices as with the overburden. Forty thousand pounds of thrust are used for drilling the coal on two 25-foot benches.

Reclamation consists of leveling spoil piles and the deposition of sub-soil and topsoil. Earthmoving and deposition will be handled by the 20-cubic-yard elevating scraper and leveling is accomplished by a 300-hp dozer. Mulching, seeding, and fertilizing are contracted.

Electrical power distribution is supplied through transmission lines. The voltage is reduced at the main substation, and the primary voltage pole line is carried in advance of and parallel to the pit highwall. Laterals (ground cables) are run at intervals of 1,500 feet to the switch houses near the highwall and then to the mining equipment. The switch houses and laterals are moved back as the pit advances.

SHOVEL-TRUCK MINING SYSTEM

Shovel-truck mining is characterized by excellent production variability compared with the other two mining methods. This method of mining offers great versatility in material handling, but maximum production can only be achieved by rigidly engineered, coordinated, and scheduled operating procedures. The principal advantages in shovel-truck stripping are the natural stratification in the backfilling process and excellent production flexibility.

Shovels consist of a lower frame and crawlers, a revolving frame, a boom, and a dipper stick and dipper. The boom is attached to the front end of the revolving frame and is supported by tension members anchored at the outer end of the boom and to the top of the gantry. A crowding mechanism mounted on the boom forces the dipper stick outward and approximately parallel to the bench. The dipper is hoisted by winches through wire cables connected to the dipper.

A shovel digs by forcing the dipper (crowding) through the material and then hoisting the load. The shovel then rotates to position the dipper over the hauler and the material is dumped by releasing the floor of the dipper.

When considering shovel-truck mining methods as a viable method of coal extraction, required production is the primary design parameter. The equipment must fulfill current production requirements and it must have enough flexibility to be integrated into any changes in the future mining plan.

Compatible haulage unit tonnage capacities are usually three to five times the shovel-dipper capacity in cubic yards, and bench heights are limited to 5 feet less than the cutting height of the shovel. Berm width, working slopes, etc., are a function of equipment, but major consideration must be given to the geology.

Cycle times for both the shovel and truck must be determined. There should be no waiting time in the shovel cycle. This is accomplished by finding a ratio of trucks to shovels necessary to maintain a constant loading cycle.

All equipment should perform at maximum possible efficiency. It is not an acceptable practice to fill a truck with a partial-dipper load or load a truck with an undercapacity load; this tends to waste movement and raise costs. All equipment should possess compatibility.

The width of the berm should be sufficient to provide areas for passing and clearance to avoid tracking around shovels.

The described mining method is a backfill four-bench system employing two 20-cubic-yard shovels and eight 120-ton rear dump trucks for overburden removal and for utilizing two 8-cubic-yard coal loading shovels and eight 85-ton rear dump coal haulers for coal mining. Two 120-ton and two 85-ton trucks are included as spares.

The initial mining cut is 120 feet deep and the benches begin production when the proper depth is attained for each bench. Overburden and topsoil are stored to the crest and sides of the cut until berm, slopes, and floor widths are in proper relation to the backfilling process. Minimum berm (bench surface) was assumed to be 200 feet.

Reclamation is begun and continued during the mining. Reclamation consists of regrading followed by contract mulching, seeding, and fertilizing. Overburden drilling and blasting, coal preparation, and coal exploitation are similar to the dragline mine.

Electrical power requirements were designed by meeting the voltage specifications of the mining equipment. The power must then be further reduced for auxiliary and low voltage equipment and fixtures. The primary voltage line is carried in advance of and parallel to the highwall and then the electricity is distributed to the equipment.

SCRAPER MINING SYSTEM

Scraper mining offers a high degree of versatility and mobility. The economics and practical ranges of this method occur in short hauls and easily loaded and spread materials (unconsolidated). The successful application of scraper or scraper-dozer mining lies in the proper coordination of mining machines and production cycles. Scrapers are usually employed in low-material volumes or in addition to other stripping equipment.

Most scraper applications are used in rocks such as friable shales or coals for one-way hauls of 1,000 to 5,000 feet. Some recently manufactured scrapers can handle ripped or blasted rock up to 2 feet but tire wear, maintenance costs, and downtime are increased. Loading materials of this nature can cause extreme damage to tires and undercarriage.

Scrapers have a low cost per ton in short- to medium-haul ranges while providing maximum flexibility in stripping and reclamation plans. When scrapers are employed, the differences in digging characteristics and economical transporting distances must be considered and compared with other loading and hauling methods.

There are three major types of wheeled scrapers: The standard, tandem powered, and either single or dual-engine elevating scrapers. The standard scraper is a two-axle, tractor-scraper combination having a single forward-mounted diesel engine with front-wheeled drive. They range from 20- to 54-cubic-yard heaped capacity with up to 550 hp. Tandem-powered scrapers are similar to the standard scraper but feature an additional rear engine and all-wheel drive for greater loading power and gradability. These are manufactured up to 54-heaped cubic-yard capacity and range up to 950 hp. The elevating scrapers are equipped with an elevating conveyor in front of the cutting edge to ease loading. The elevating scrapers are effective in situations of independent loading and very short hauls. The other types of scrapers may or may not have to use a pusher (dozer or other scrapers to assist in loading). Only elevating or push-pull scrapers (scrapers hooked together while both are loading) can reach full load without a pusher. The type of scraper or combination of scrapers and pushers is dependent on the particular situation and geologic characteristics of the area.

A scraper work cycle consists of load, haul, maneuver and spread, and return. Load times vary with available scraper power and capacity, pusher size and availability, and job efficiency. Haul time is dependent on load, available power, traction, grade, job conditions, and distance. Maneuver and spread is related to the size and type of scraper, and return time is the time to return from the dump site.

Scrapers load by raising the apron (front of bowl) to allow material to enter and by lowering the cutting edge into the material to loosen it. The material is forced back into the bowl. On elevating scrapers the elevating conveyor helps break up the material and conveys it to the top of the bowl. This has the advantage of not having to displace the previously loaded material and, in effect, increases the pulling power of the scraper.

Before hauling, the apron is closed and the cutting edge is raised. When the dump area is approached, the apron is lowered and a hydraulic ejector is activated to empty the bowl. The scraper unloads while in motion.

In specifically selecting a scraper system, distances and unit production costs are the decisive and comparative parameters. Each type of scraping system that can be effectively employed must be considered and costed to arrive at the proper equipment selection.

Tandem-powered push-pull scrapers were used for this estimate because they possess the traction and power to self-load in unconsolidated and harder materials. Other scrapers can assist in loading. The forward scraper is pushed to help load, and then the rear scraper pulled to be assisted in its loading. This type of scraper was deemed to be the most practical and economical for handling the assumed overburden.

The mine is a moving panel employing a progressive backfill system. The topsoil is removed in advance of the panel and is deposited to the backfilled areas by way of a 20-cubic-yard elevating scraper. The overburden is pre-blasted and then removed by 10 tandem-powered push-pull scrapers. Overburden preparation, coal mining, and reclamation are the same as in previous estimates. The panel is 400 feet wide and the length was assumed to be 2,000 feet.

CONCLUSION

This report is a preliminary cost analysis of mining a hypothetical area with assumed particular conditions by various mining methods. All mining situations are unique and costs are inherently different. Assumptions and limitations in any cost analysis should be weighted to the particular situation by the discretion of the designer relying on past experience and available information. The logistics, management problems, depreciation, and general rate of return will vary with locality, method, ease and efficiency of operation, and fluctuating prices and mining costs.

Generally the unit cost of moving a cubic yard of material by dragline is less expensive than the other methods. Because of the assumed suspended load, design production limit, and the assumed constant property life, the chosen dragline model was equipped with a smaller than normal bucket. In a normal mining situation the dragline would be equipped with a larger bucket.

The rate of return was evaluated by assuming a yearly cash flow based on an assumed sales realization. The rate of return evaluates the relative profitability of a project at a constant return. A rate of return of at least 15 percent on equity capital after taxes for a strip mine is considered

minimum to warrant further interest. No cost of capital was included. The rate of return is shown in the following tabulation:

Mining system	Initial capital requirements	Deferred capital requirements	Total capital requirements	Rate of return at \$5.24 per ton, pct
Dragline.....	\$50,693,190	\$19,987,213	\$70,680,403	16.12
Shovel-truck.....	51,766,210	38,286,245	90,052,455	12.13
Scraper.....	46,654,048	53,560,429	100,214,478	13.18

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APPENDIX A.--DESIGN PARAMETERS

Assumptions:	
Seam thickness.....	feet.. 50
Overburden depth.....	do... 70
Degrees dip.....	0
Coal specific gravity.....	1.25
Annual coal production.....	tons.. 5,000,000
Stripping volume per acre.....	cu yd.. 112,931
Annual stripping volume.....	cu yd.. 7,386,131
Strip ratio.....	cu yd/ton.. 1.48
Swell (overburden).....	swell factor.. 0.735
Compaction.....	original volume.. 1.20
Density (overburden).....	lb/cu ft.. 125
Recovery.....	percent.. 90
Angle of highwall (where applicable).....	degrees.. 71
Angle of repose.....	do.... 38.5
Stripping: Scheduled operating hours--annually:	
Dragline.....	8,640
Shovels.....	4,000
Scrapers.....	4,000
Drills.....	4,000
Blasting:	
Jointing system from cut section.....	degrees.. 45
Powder factor:	
Dragline system.....	lb/cu yd.. 0.40
Shovel-truck system.....	lb/cu yd.. 0.30
Scraper system.....	lb/cu yd.. 0.70
Coal mining:	
Scheduled operating hours--annually.....	4,000
Jointing system from cut section.....	degrees.. 45
Powder factor.....	lb/cu yd.. 0.15
Average haul (one-way) from pit crest to tipple.....	feet.. 10,000
Speed limits (entering pit).....	mi/hr.. 10
Speed limits (leaving pit).....	mi/hr.. 15

NOTE.--Generally, no blending of coal was done at mine site, and no preparation of coal was done except for sizing to 1.5 x 0 mesh.

APPENDIX B.--DRAGLINE MINING SYSTEM

TABLE B-1. - Total estimated capital requirements, dragline mining system

Exploration, buildings, roads, rail spur.....	\$18,527,000
Unit-train loading facilities.....	1,319,825
Mining equipment.....	18,978,619
Total direct.....	38,825,444
Field indirect.....	776,508
Total construction.....	39,601,952
Engineering.....	792,039
Overhead and administration.....	2,019,699
Contingency.....	4,241,369
Fee.....	933,101
Total plant cost.....	47,588,162
Interest during construction.....	1,189,704
Working capital.....	1,915,324
Total initial capital requirements.....	50,693,190
Estimated deferred capital.....	19,987,213
Total capital requirements.....	70,680,403

TABLE B-2. - Estimated working capital, dragline mining system

Direct labor.....	3 months..	\$562,906
Payroll overhead.....	do.....	197,017
Operating supplies.....	do.....	472,154
Indirect cost.....	4 months..	207,012
Fixed cost, 0.5 percent of insurance base.....		237,941
Spare parts, 15 percent of annual spare parts.....		64,174
Miscellaneous expense.....		174,120
Total.....		1,915,324

TABLE B-3. - Capital investment summary, dragline mining system

Quantity	Item	Unit cost	Capital cost	Depreciation schedule, years	Yearly charge
1.....	Dragline (erected).....	\$9,650,677	\$9,650,677	20	\$482,534
2.....	Coal loading shovels (erected).....	1,256,794	2,513,588	20	125,679
3.....	Coal drills.....	229,250	229,250	8	28,656
10.....	Coal haulers, 85-ton.....	378,378	3,783,780	4	945,945
1.....	Dozer.....	181,514	181,154	3	60,384
1.....do.....	181,514	181,154	5	72,606
1.....	Overburden drill.....	668,100	668,100	12	55,675
1.....	Scraper (elevating).....	205,618	205,618	5	41,124
1.....	Front-end loader.....	63,404	63,404	5	12,683
1.....	Grader.....	124,319	124,319	3	41,440
1.....	Forklift.....	12,707	12,707	10	1,271
1.....	Crane.....	54,000	54,000	10	5,400
1.....	Explosive truck.....	19,650	19,650	10	1,965
1.....	Lube truck.....	16,768	16,768	10	1,677
1.....	Utility tractor.....	9,700	9,700	5	1,940
1.....	Supply truck.....	8,900	8,900	10	890
1.....	Mechanic truck.....	11,921	11,921	10	1,192
1.....	Electrician truck.....	9,840	9,840	10	984
1.....	Flatbed truck.....	8,829	8,829	10	883
1.....	Tire changer.....	29,800	29,800	10	2,980
	Tires.....	268,601	268,601	-	-
12.....	Personnel trucks.....	7,598	91,176	5	18,235
2.....	Carryalls.....	7,075	14,150	5	2,830
1.....	Ambulance.....	9,441	9,441	20	472
1.....	Pump, casing, and well.....	35,000	35,000	20	1,750
3.....	Pumps.....	13,100	13,100	10	1,310
3.....	Lights and tower.....	6,223	18,669	10	1,867
	Communications.....	9,000	9,000	10	900
	Cable and cable handler.....	26,240	26,240	20	
	Electrical equipment.....	258,100	258,100	20	
	Exploration.....	98,000	98,000	20	4,900
	Coal lease.....	132,260	132,260	-	-
	Environmental impact statement.....	205,670	205,670	20	10,280
	Explosive storage.....	15,980	15,980	20	799
	Warehouse, supply room, bulk storage, maintenance shop, machine shop, rail spur, etc.....	18,527,000	18,527,000	20	926,350
	Unit train loading.....	1,319,825	1,319,825	20	65,991
	Field indirect, engineering, overhead and administration, contingency, fee, and interest.....	-	-	20	497,621
	Interim equipment replacement.....	-	-	-	149,904
	Total.....		38,825,444		3,569,117

TABLE B-4. - Annual cost of supervisory personnel, dragline mining system

Number	Position	Salary/year	Annual cost
1.....	Superintendent.....	\$40,000	\$40,000
1.....	Assistant superintendent.....	36,000	36,000
3.....	Pit foremen.....	24,000	72,000
1.....	Shooter foreman.....	22,000	22,000
1.....	Assistant shooter foreman.....	21,000	21,000
1.....	Tipple foreman.....	22,000	22,000
1.....	Assistant tipple foreman.....	21,000	21,000
1.....	Chief electrician.....	23,000	23,000
1.....	Assistant chief electrician.....	22,000	22,000
1.....	Master mechanic.....	23,000	23,000
1.....	Assistant master mechanic.....	22,000	22,000
1.....	Shop foreman.....	22,000	22,000
1.....	Assistant shop foreman.....	21,000	21,000
1.....	Reclamation foreman.....	22,000	22,000
1.....	Mine clerk.....	16,000	16,000
1.....	Purchasing agent.....	21,000	21,000
1.....	Weighmaster.....	18,000	18,000
1.....	Mining engineer.....	23,000	23,000
1.....	Assistant engineer.....	17,400	17,400
1.....	Surveyor.....	15,600	15,600
2.....	Rodmen.....	12,000	24,000
1.....	Secretary.....	10,000	10,000
1.....	Warehouseman.....	15,600	15,600
1.....	Laboratory.....	12,000	12,000
	Total.....		561,600

TABLE B-5. - Annual cost of hourly personnel, dragline mining system

Number	Position	Wage/ hour	Shift differential ¹	Overtime	Annual cost
4....	Dragline operators.....	\$9.56	\$0.08	\$41,645	\$118,765
4....	Shovel operators.....	9.56	.08		76,800
8....	Oilers.....	8.92	.08	38,800	182,800
16....	Mobile equipment operators II.....	8.92	.08		286,720
10....	Mobile equipment operators I.....	8.49	.08		170,600
3....	Drill operators.....	8.49	.08		51,100
2....	Drill helpers.....	7.98	.08		32,080
2....	Shooters.....	8.49	.08		33,960
2....	Groundmen.....	8.92	.08		35,840
2....	Service truck drivers.....	7.89	.08		31,720
2....	Tipple attendants.....	7.98	.08		32,080
2....	Tipple repairmen.....	8.49	.08		34,120
2....	Utility men.....	7.89	.08		31,720
2....	Pumpmen.....	7.89	.08		31,720
1....	Greaser.....	8.49	.08		17,300
6....	Welders.....	8.92	.08		107,520
6....	Mechanics.....	9.23	.08		111,240
3....	Mechanic helpers.....	7.98	.08		48,040
1....	Machinist.....	9.23	.08		18,460
6....	Electricians.....	9.23	.08		111,240
7....	Laborers--unskilled.....	7.89	.08		110,940
1....	Janitor.....	7.63	.08		15,260
	Total.....				1,690,025

¹ Absenteeism is not considered.

TABLE B-6. - Estimated annual production cost, dragline mining system

	Cost per ton	Total annual cost
Direct cost:		
Labor.....	\$0.338	\$1,690,025
Supervision.....	.112	561,600
Total.....	.450	2,251,625
Operating supplies:		
Spare parts.....	.085	427,825
Explosives.....	.075	374,398
Fuel, oil, and lubrication.....	.083	416,300
Tires.....	.086	428,400
Crushed limestone.....	.014	70,000
Miscellaneous.....	.034	171,692
Total.....	.377	1,888,615
Power.....	.043	215,145
Payroll overhead.....	.158	788,069
Welfare (\$1.54 classified/hr).....	.073	365,165
Royalty, rent (royalty 12.5 percent and severance 10 percent) ¹	1.191	5,953,570
Strip license.....	.049	247,500
Reclamation fund.....	.026	130,224
Total.....	1.540	7,699,673
Total direct cost.....	2.367	11,839,913
Total indirect cost.....	.124	621,036
Fixed cost:		
Taxes and insurance.....	.190	951,763
Depreciation.....	.713	3,569,117
Total fixed cost.....	.903	4,520,880
Tipple to train loading.....	.150	750,000
Total annual production cost.....	3.544	17,731,829

¹Approximate assumed average for the northern Great Plains States.

APPENDIX C.--SHOVEL-TRUCK MINING SYSTEM

TABLE C-1. - Total estimated capital requirements,
shovel-truck mining system

Exploration, buildings, roads, and rail spur.....	\$19,365,620
Unit-train loading facilities.....	1,319,825
Mining equipment.....	18,647,770
Total direct.....	39,333,215
Field indirect.....	786,664
Total construction.....	40,119,879
Engineering.....	802,398
Overhead and administration.....	2,046,114
Contingency.....	4,296,839
Fee.....	945,305
Total plant cost.....	48,210,535
Interest during construction.....	1,205,263
Working capital.....	2,350,412
Total initial capital requirements.....	51,766,210
Estimated deferred capital.....	38,286,245
Total capital requirements.....	90,052,455

TABLE C-2. - Estimated working capital,
shovel-truck mining system

Direct labor.....3 months..	\$647,665
Payroll overhead.....do.....	226,683
Operating supplies.....do.....	697,566
Indirect cost.....4 months..	269,019
Fixed cost, 0.5 percent of insurance base.....	241,053
Spare parts, 15 percent of annual spare parts.....	54,752
Miscellaneous expense.....	213,674
Total.....	2,350,412

TABLE C-3. - Capital investment summary, shovel-truck mining system

Quantity	Item	Unit cost	Capital cost	Depreciation schedule, years	Yearly charge
2.....	Shovels, overburden.....	\$2,641,480	\$5,283,960	20	\$264,148
2.....	Coal loading shovels.....	1,256,794	2,513,588	20	125,679
10.....	Trucks, 120-ton, overburden.....	460,852	4,608,520	4	1,152,130
10.....	Coal haulers, 85-ton.....	378,378	3,783,780	4	945,945
1.....	Dozer (rubber-tired).....	131,622	131,622	5	26,324
2.....	Dozers.....	181,514	363,028	5	72,606
1.....	Overburden drill.....	668,100	668,100	12	55,675
1.....	Coal drill.....	229,250	229,250	8	28,656
1.....	Scraper (elevating).....	205,618	205,618	5	41,124
1.....	Front-end loader.....	63,414	63,414	5	12,683
1.....	Grader.....	124,319	124,319	3	41,440
1.....	Forklift.....	12,707	12,707	10	1,271
1.....	Crane.....	43,000	43,000	10	4,300
1.....	Explosive truck.....	19,650	19,650	10	1,965
1.....	Lube truck.....	16,768	16,768	10	1,677
1.....	Utility tractor.....	9,700	9,700	5	1,940
1.....	Supply truck.....	8,900	8,900	10	890
1.....	Mechanic truck.....	11,921	11,921	10	1,192
1.....	Electrician truck.....	9,840	9,840	10	984
1.....	Flatbed truck.....	8,829	8,829	10	883
1.....	Tire changer.....	29,800	29,800	10	2,980
	Tires.....	396,130	396,130	-	-
12.....	Personnel trucks.....	7,598	91,176	5	18,235
2.....	Carryalls.....	7,075	14,150	5	2,830
1.....	Ambulance.....	9,441	9,441	20	472
1.....	Pump, casing, and well.....	35,000	35,000	20	1,750
3.....	Pumps.....	13,100	13,100	10	1,310
4.....	Lights and tower.....	6,223	24,892	10	2,489
	Communications.....	9,000	9,000	10	900
	Cable and cable handler.....	31,240	31,240	20	1,562
	Electrical equipment.....	264,100	264,100	20	13,205
	Exploration.....	98,000	98,000	20	4,900
	Coal lease.....	132,260	132,260	-	-
	Environmental impact statement.....	205,670	205,670	20	10,280
	Explosive storage.....	15,980	15,980	20	799
	Warehouse, supply room, bulk storage, maintenance shop, rail spur, etc.....	18,527,000	18,527,000	20	926,350
	Unit train loading.....	1,319,825	1,319,825	20	65,991
	Field indirect, engineering, overhead and administration, contingency, fee, and interest.....	-	-	20	504,129
	Interim equipment replacement.....	-	-	-	287,146
	Total.....	-	39,333,215	-	4,626,840

TABLE C-4. - Annual cost of supervisory personnel, shovel-truck mining system

Number	Position	Salary/year	Annual cost
1....	Superintendent.....	\$40,000	\$40,000
1....	Assistant superintendent.....	36,000	36,000
2....	Pit foremen.....	24,000	48,000
1....	Shooter foreman.....	22,000	22,000
1....	Assistant shooter foreman.....	21,000	21,000
1....	Tipple foreman.....	22,000	22,000
1....	Assistant tipple foreman.....	21,000	21,000
1....	Chief electrician.....	23,000	23,000
1....	Assistant chief electrician.....	22,000	22,000
1....	Master mechanic.....	23,000	23,000
1....	Assistant master mechanic.....	22,000	22,000
1....	Shop foreman.....	22,000	22,000
1....	Assistant shop foreman.....	21,000	21,000
1....	Reclamation foreman.....	22,000	22,000
1....	Mine clerk.....	16,000	16,000
1....	Purchasing agent.....	21,000	21,000
1....	Weighmaster.....	18,000	18,000
1....	Mining engineer.....	23,000	23,000
1....	Assistant engineer.....	17,400	17,400
1....	Surveyor.....	15,600	15,600
2....	Rodmen.....	12,000	24,000
1....	Secretary.....	10,000	10,000
1....	Warehouseman.....	15,600	15,600
1....	Laboratory.....	12,000	12,000
	Total.....	-	537,600

TABLE C-5. - Annual cost of hourly personnel, shovel-truck mining system

Number	Position	Wage/ hour	Shift differential ¹	Annual cost
8....	Shovel operators.....	\$9.56	\$0.08	\$153,600
8....	Oilers.....	8.92	.08	143,360
32....	Mobile equipment operators II.....	8.92	.08	573,440
11....	Mobile equipment operators I.....	8.49	.08	187,580
3....	Drill operators.....	8.49	.08	51,100
2....	Drill helpers.....	7.98	.08	32,080
2....	Shooters.....	8.49	.08	33,960
4....	Groundmen.....	8.92	.08	71,680
2....	Service truck drivers.....	7.89	.08	31,720
2....	Tipple attendants.....	7.98	.08	32,080
2....	Tipple repairmen.....	8.49	.08	34,120
2....	Utility men.....	7.89	.08	31,720
2....	Pumpmen.....	7.89	.08	31,720
2....	Greasers.....	8.49	.08	34,600
6....	Welders.....	8.92	.08	107,520
9....	Mechanics.....	9.23	.08	166,780
4....	Mechanic helpers.....	7.98	.08	64,160
1....	Machinist.....	9.23	.08	18,460
6....	Electricians.....	9.23	.08	111,240
8....	Laborers--unskilled.....	7.89	.08	126,880
1....	Janitor.....	7.63	.08	15,260
	Total.....	-	-	2,053,060

¹Absenteeism is not considered.

TABLE C-6. - Estimated annual production cost,
shovel-truck mining system

	Cost per ton	Total annual cost
Direct cost:		
Labor.....	\$0.411	\$2,053,060
Supervision.....	.107	537,600
Total.....	.518	2,590,660
Operating supplies:		
Spare parts.....	.073	365,013
Explosives.....	.064	321,846
Fuel, oil, and lubrication.....	.166	830,944
Tires.....	.190	948,800
Crushed scoria.....	.014	70,000
Miscellaneous.....	.051	253,660
Total.....	.558	2,790,263
Power.....	.028	128,742
Payroll overhead.....	.181	906,731
Welfare (\$1.54 classified/hr).....	.072	360,360
Royalty, rent (royalty 12.5 percent and severance 10 percent) ¹	1.191	5,953,570
Strip license.....	.049	247,500
Reclamation fund.....	.026	130,224
Total.....	1.545	7,727,127
Total direct cost.....	2.621	13,108,050
Total indirect cost.....	.161	807,138
Fixed cost:		
Taxes and insurance.....	.193	964,210
Depreciation.....	.925	4,626,840
Total fixed cost.....	1.118	5,591,050
Tipple to train loading.....	.150	750,000
Total annual production cost.....	4.051	20,256,238

¹Approximate assumed average of the severance taxes in the northern Great Plains States.

APPENDIX D.--SCRAPER MINING SYSTEM

TABLE D-1. - Total estimated capital requirements, scraper mining system

Exploration, buildings, roads, and rail spur.....	\$19,272,961
Unit-train loading facilities.....	1,319,825
Mining equipment.....	14,702,015
Total direct.....	35,294,801
Field indirect.....	705,896
Total construction.....	36,000,697
Engineering.....	720,014
Overhead and administration.....	1,836,036
Contingency.....	3,855,675
Fee.....	848,248
Total plant cost.....	43,260,670
Interest during construction.....	1,081,546
Working capital.....	2,311,832
Total initial capital requirements.....	46,654,048
Estimated deferred capital.....	53,560,429
Total capital requirements.....	100,214,478

TABLE D-2. - Estimated working capital, scraper mining system

Direct labor.....3 months..	\$588,160
Payroll overhead.....do.....	205,856
Operating supplies.....do.....	776,206
Indirect cost.....4 months..	272,846
Fixed cost, 0.5 percent of insurance base.....	216,303
Spare parts, 15 percent of annual spare parts.....	42,295
Miscellaneous expense.....	210,167
Total.....	2,311,832

TABLE D-3. - Capital investment summary, scraper mining system

Quantity	Item	Unit cost	Capital cost	Depreciation, schedule, years	Yearly charge
13.....	Scrapers.....	\$425,795	\$5,535,333	3	\$1,845,111
2.....	Coal loading shovels (erected).....	1,256,794	2,513,589	20	125,679
1.....	Coal drill.....	229,250	229,250	8	28,656
10.....	Coal haulers, 85-ton.....	378,378	3,783,780	4	945,945
4.....	Dozers.....	181,514	726,054	5	145,210
1.....	Overburden drill.....	668,100	668,100	12	55,675
1.....	Scraper (elevating).....	205,618	205,618	5	41,124
1.....	Front-end loader.....	63,404	63,404	5	12,681
1.....	Grader.....	124,319	124,319	3	41,439
1.....	Forklift.....	12,707	12,707	10	1,271
1.....	Crane.....	26,200	26,200	10	2,620
1.....	Explosive truck.....	19,650	19,650	10	1,965
1.....	Lube truck.....	16,768	16,768	10	1,677
1.....	Utility tractor.....	9,700	9,700	5	1,940
1.....	Supply truck.....	8,900	8,900	10	890
1.....	Mechanic truck.....	11,921	11,921	10	1,192
1.....	Electrician truck.....	9,840	9,840	10	984
1.....	Flatbed truck.....	8,829	8,829	10	883
1.....	Tire changer.....	26,200	26,200	10	2,620
	Tires.....	-	603,602	-	-
12.....	Personnel trucks.....	7,598	91,176	5	18,235
1.....	Carryall.....	7,075	7,075	5	1,415
1.....	Ambulance.....	9,441	9,441	20	472
1.....	Pump, casing, and well.....	35,000	35,000	20	1,750
	Pumps.....	13,100	13,100	10	1,310
3.....	Lights and tower.....	6,223	18,670	10	1,867
	Communications.....	9,000	9,000	10	900
	Cable and cable handler.....	21,240	21,240	20	1,062
	Electrical equipment.....	187,600	187,600	20	9,380
	Exploration.....	98,000	98,000	20	4,900
	Coal lease.....	132,260	132,260	-	-
	Environmental impact statement.....	205,670	205,670	20	10,284
	Explosive storage.....	15,980	15,980	20	799
	Warehouse, supply room, bulk storage, maintenance shop, machine shop, rail spur, etc.....	18,527,000	18,527,000	20	926,350
	Unit train loading.....	1,319,825	1,319,825	20	65,991
	Field indirect, engineering, overhead and administration, contingency, fee, and interest.....	-	-	20	452,369
	Interim equipment replacement.....	-	-	-	401,703
	Total.....	-	35,294,801	-	5,156,349

TABLE D-4. - Annual cost of supervisory personnel, scraper mining system

Number	Position	Salary/year	Annual cost
1.....	Superintendent.....	\$40,000	\$40,000
1.....	Assistant superintendent.....	36,000	36,000
2.....	Pit foreman.....	24,000	48,000
1.....	Shooter foremen.....	22,000	22,000
1.....	Assistant shooter foreman.....	21,000	21,000
1.....	Tipple foreman.....	22,000	22,000
1.....	Assistant tipple foreman.....	21,000	21,000
1.....	Chief electrician.....	23,000	23,000
1.....	Assistant chief electrician.....	22,000	22,000
1.....	Master mechanic.....	23,000	23,000
1.....	Assistant master mechanic.....	22,000	22,000
1.....	Shop foreman.....	22,000	22,000
1.....	Assistant shop foreman.....	21,000	21,000
1.....	Reclamation foreman.....	22,000	22,000
1.....	Mine clerk.....	16,000	16,000
1.....	Purchasing agent.....	21,000	21,000
1.....	Weighmaster.....	18,000	18,000
1.....	Mining engineer.....	23,000	23,000
1.....	Assistant engineer.....	17,400	17,400
1.....	Surveyor.....	15,600	15,600
2.....	Rodmen.....	12,000	24,000
1.....	Secretary.....	10,000	10,000
1.....	Warehouseman.....	15,600	15,600
1.....	Laboratory.....	12,000	12,000
	Total.....	-	537,600

TABLE D-5. - Annual cost of hourly personnel, scraper mining system

Number	Position	Wage/ hour	Shift differential ¹	Annual cost
4....	Shovel operators.....	\$9.56	\$0.08	\$76,800
4....	Oilers.....	8.92	.08	71,680
16....	Mobile equipment operators II.....	8.92	.08	286,720
32....	Mobile equipment operators I.....	8.49	.08	545,920
3....	Drill operators.....	8.49	.08	51,100
2....	Drill helpers.....	7.98	.08	32,080
2....	Shooters.....	8.49	.08	33,960
2....	Service truck drivers.....	7.89	.08	31,720
2....	Tipple attendants.....	7.98	.08	32,080
2....	Tipple repairmen.....	8.49	.08	34,120
2....	Utility men.....	7.89	.08	31,720
2....	Pumpmen.....	7.89	.08	31,720
2....	Greasers.....	8.49	.08	34,600
5....	Welders.....	8.92	.08	89,520
8....	Mechanics.....	9.23	.08	148,320
4....	Mechanic helpers.....	7.98	.08	64,160
1....	Machinist.....	9.23	.08	18,460
4....	Electricians.....	9.23	.08	74,160
7....	Laborers--unskilled.....	7.89	.08	110,940
1....	Janitor.....	7.63	.08	15,260
	Total.....	-	-	1,815,040

¹ Absenteeism is not considered.

TABLE D-6. - Estimated annual production cost, scraper mining system

	Cost per ton	Total annual cost
Direct cost:		
Labor.....	\$0.363	\$1,815,040
Supervision.....	.107	537,600
Total.....	.470	2,352,640
Operating supplies:		
Spare parts.....	.056	281,968
Explosives.....	.113	564,906
Fuel, oil and lubrication.....	.260	1,301,248
Tires.....	.138	689,324
Crushed scoria.....	.014	70,000
Miscellaneous.....	.039	197,376
Total.....	.621	3,104,822
Power.....	.021	108,060
Payroll overhead.....	.154	823,424
Welfare (\$1.54 classified/hr)065	323,400
Royalty, rent (royalty 12.5 percent and severance 10 percent) ¹	1.191	5,953,570
Strip license.....	.049	247,500
Reclamation fund.....	.026	130,224
Total.....	1.517	7,586,178
Total direct cost.....	2.608	13,043,640
Total indirect cost.....	.163	818,619
Fixed cost:		
Taxes and insurance.....	.173	865,213
Depreciation.....	1.031	5,156,349
Total fixed cost.....	1.204	6,021,562
Tipple to train loading.....	.150	750,000
Total annual production cost.....	4.127	20,633,821

¹Approximate assumed average for the northern Great Plains States.

APPENDIX E.--CASH FLOW ANALYSIS

TABLE E-1. - Comparable production costs

	Cost per ton		
	Dragline	Shovel-truck	Scraper
Direct cost:			
Labor.....	\$0.338	\$0.411	\$0.363
Supervision.....	.112	.107	.107
Total.....	.450	.518	.470
Operating supplies:			
Spare parts.....	.085	.073	.056
Explosives.....	.075	.064	.113
Fuel, oil, and lubrication.....	.083	.166	.260
Tires.....	.086	.190	.138
Crushed limestone.....	.014	.014	.014
Miscellaneous.....	.034	.051	.039
Total.....	.377	.558	.621
Power.....	.043	.028	.021
Payroll overhead.....	.158	.181	.154
Welfare.....	.073	.072	.065
Royalty, rent.....	1.191	1.191	1.191
Strip license.....	.049	.049	.049
Reclamation fund.....	.026	.026	.026
Total.....	1.540	1.545	1.517
Total direct cost.....	2.367	2.621	2.608
Total indirect cost.....	.124	.161	.163
Fixed cost:			
Taxes and insurance.....	.190	.193	.173
Depreciation.....	.713	.925	1.031
Total fixed cost.....	.903	1.118	1.204
Tipple to train loading.....	.150	.150	.150
Total annual production cost.....	3.544	4.051	4.127

TABLE E-2. - Cash flow analysis (\$5.24 assumed price)

Year and revenue	Dragline		Shovel-truck		Scraper	
	Capital expenditure	Net cash flow	Capital expenditure	Net cash flow	Capital expenditure	Net cash flow
0, \$0.....	\$50,693,190	-\$50,693,190	\$51,766,283	-\$51,766,283	\$46,654,048	-\$46,654,048
1, \$26,200,000.....	149,904	8,963,298	287,146	8,621,575	401,703	8,828,519
2, \$26,200,000.....	149,904	8,963,298	287,146	8,621,575	401,703	8,828,519
3, \$26,200,000.....	456,377	8,656,826	411,465	8,497,256	6,061,355	3,168,867
4, \$26,200,000.....	3,933,684	5,175,518	8,679,446	229,275	4,185,483	5,044,739
5, \$26,200,000.....	708,041	8,405,161	1,166,124	7,742,597	1,504,726	7,725,496
6, \$26,200,000.....	456,377	8,656,826	411,465	8,497,256	6,061,355	3,168,867
7, \$26,200,000.....	149,904	8,963,298	287,146	8,621,575	401,703	8,828,519
8, \$26,200,000.....	4,162,934	4,950,268	8,908,696	25	4,414,733	4,815,489
9, \$26,200,000.....	456,377	8,656,826	411,465	8,497,256	6,061,355	3,168,867
10, \$26,200,000.....	921,288	8,191,914	1,374,531	7,534,190	1,660,315	7,569,907
11, \$26,200,000.....	149,904	8,963,298	287,146	8,621,575	401,703	8,828,519
12, \$26,200,000.....	4,908,257	4,204,946	9,471,865	-563,144	513,235	-1,283,013
13, \$26,200,000.....	149,904	8,963,298	287,146	8,621,575	401,703	8,828,519
14, \$26,200,000.....	149,904	8,963,298	287,146	8,621,575	401,703	8,828,519
15, \$26,200,000.....	1,014,514	8,098,688	1,290,173	7,618,548	7,164,832	2,065,390
16, \$26,200,000.....	4,162,934	4,950,268	8,908,696	25	4,414,733	4,815,489
17, \$26,200,000.....	194,904	8,963,298	287,146	8,621,575	401,703	8,828,519
18, \$26,200,000.....	456,377	8,656,826	411,465	8,497,256	5,937,036	3,293,186
19, \$26,200,000.....	149,904	8,963,298	287,146	8,621,575	401,703	8,828,519
¹ 20, \$26,200,000.....	-2,354,806	11,468,008	-2,733,206	11,641,950	-4,772,645	14,002,867
Operating cost.....	\$17,731,829	-	\$20,256,238	-	\$20,633,821	-
Depreciation.....	\$3,569,117	-	\$4,626,840	-	\$5,156,349	-
Rate of return..percent..	16.12	-	12.13	-	13.18	-

¹Undepreciated equipment value and working capital salvaged in year 20.

