

**PB 297306**

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**DEVELOPMENT OF CONCEPTS  
FOR SURFACE MINING  
MODERATELY PITCHING  
COAL SEAMS**

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Prepared for:  
**UNITED STATES DEPARTMENT OF THE INTERIOR  
BUREAU OF MINES**

by:

**SKELLY AND LOY**

Engineers - Consultants  
2601 North Front Street  
Harrisburg, Pennsylvania 17110

**FINAL REPORT — SUMMARY VOLUME**

VOLUME I

on:

**Contract No. J0275023  
Surface Mining of Moderately Pitching Coal Seams**

**November, 1978**

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Reference to specific brands, equipment, or trade names in this report is made to facilitate understanding and does not imply endorsement by the Bureau of Mines.

## **FOREWORD**

This report was prepared by Skelly and Loy, Engineers and Consultants, 2601 North Front Street, Harrisburg, Pennsylvania under USBM Contract Number J0275023. The contract was initiated under the U.S. Bureau of Mines Extraction Technology Program. It was administered under the technical direction of the Spokane Mining Research Center with Mr. Ronald Backer acting as the Technical Project Officer. Mr. Larry Rock was the contract administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this contract during the period October 1, 1977 to March 31, 1978. This report was submitted by the authors on November 1, 1978.



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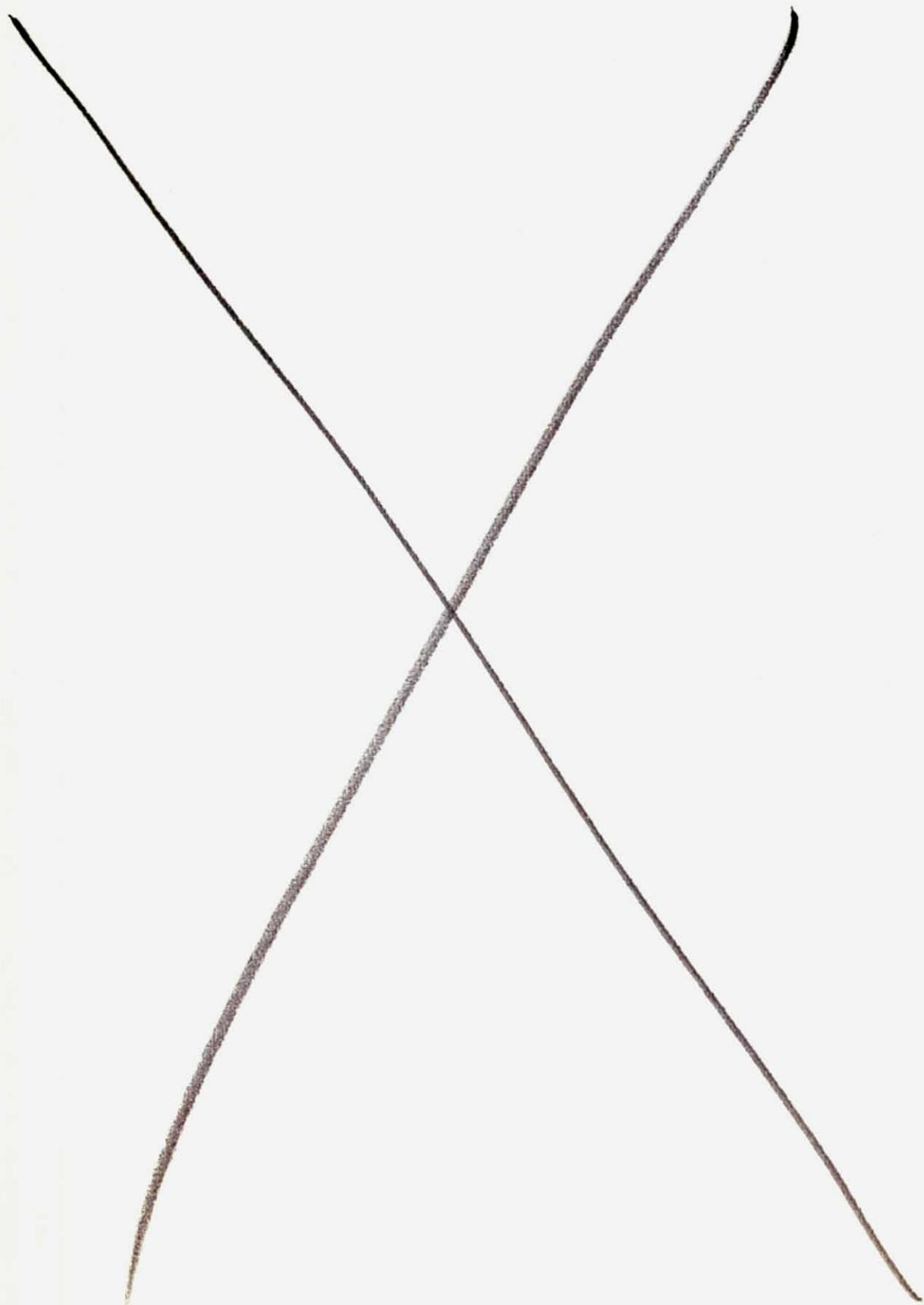
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## INTRODUCTION

Coal plays a vital role in meeting the Nation's energy requirements. Indications are that the importance of coal as a dependable, long-term energy source will increase in the foreseeable future. Many factors govern the mineability of a coal seam, and the dip of a seam exerts a marked influence on several factors affecting mineability. Moderately pitching coal seams, those dipping from 8 to 25 degrees, are found in 16 states. While many of these seams have extensive surface mineable tonnages, they are frequently not developed because of mining and reclamation problems inherent in working on a significant dip.

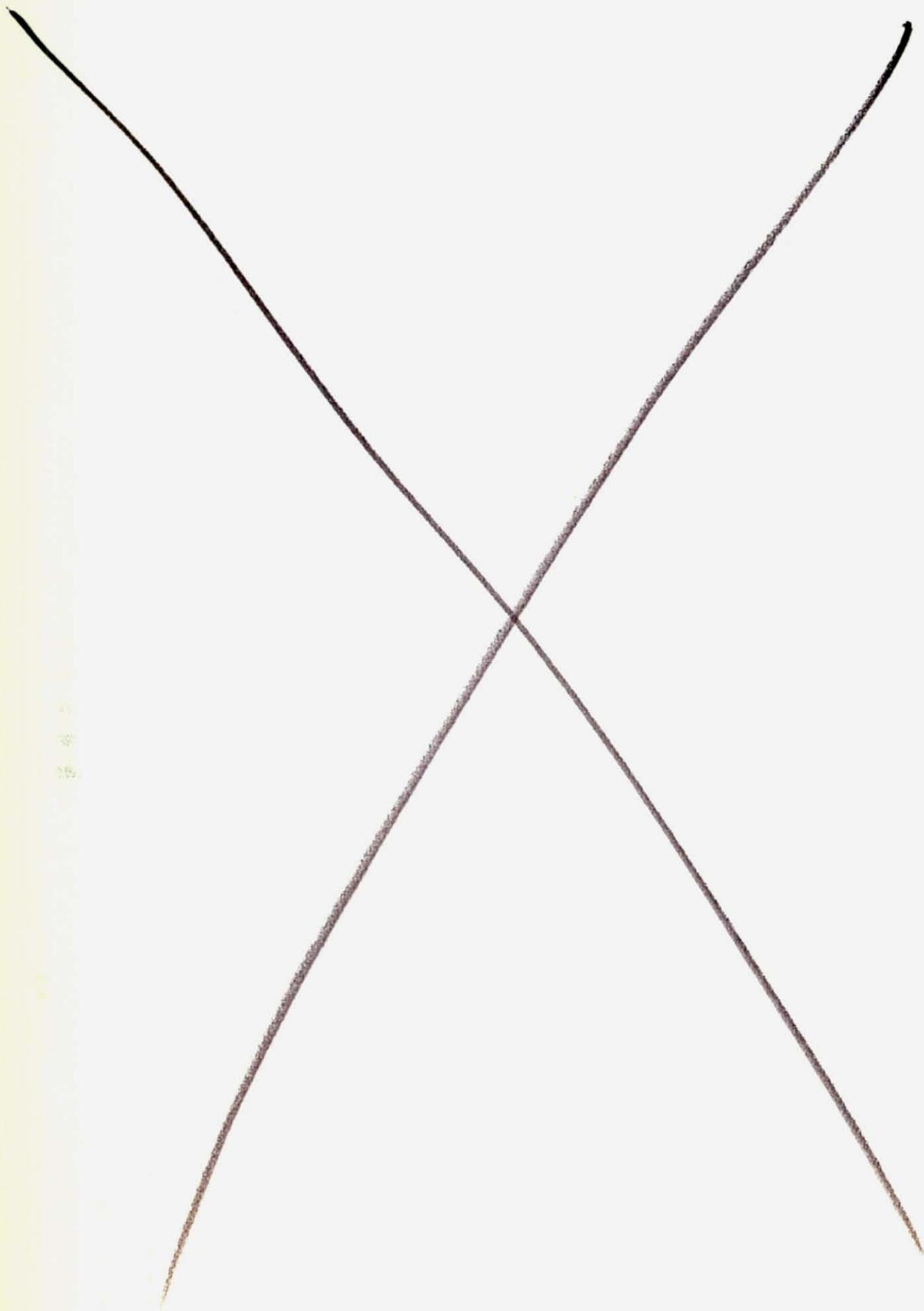
The U.S. Bureau of Mines, cognizant of valuable coal resources present in moderately pitching seams, instituted a study of the resource and mining potential of coal seams dipping from 8 to 25 degrees. Although precise figures are not available, general data sources indicate that less than 30% of annual coal production comes from surface mines operating on seams dipping within this range. For this reason the U.S. Bureau of Mines' study was aimed at documenting inherent reasons for the limited production experienced from those coal seams which comprise a significant percentage of total United States surface coal reserves. Utilizing information gained from field reconnaissance and literature searches the main thrust of this project was to attempt to develop extraction techniques designed to alleviate the operational and reclamation problems and expand the recoverable resource potential associated with surface mining of moderately pitching coal deposits.

This report presents the data, conclusions, and recommendations generated during the study of coal resources present in moderately pitched seams and mining systems employed for their recovery. Included are improved mining concepts designed to facilitate enhanced coal recovery and reclamation. Economic and operational feasibility analyses were performed on each concept, and the information from these analyses are presented.

All information and operating parameters delineated during each site visitation were carefully reviewed and analyzed for potential improvements. Particular attention was focused on the percent of available resources recovered, equipment utilization and scheduling, safety, and reclamation practices and success. At this point all available information was used to outline the baseline considerations to be applied to the concept development work efforts and representative pitched seam situations were created. By "standardizing" mining conditions, this approach ensured equitable comparison of the improved concepts developed in subsequent work.

An interdisciplinary team approach was used to develop 6 improved concepts for mining coal from seams dipping 8 to 25 degrees. Based on data from the site evaluations, a desired level of production was established. Because of the relatively low BTU value of Western coal seams, higher production levels need to be reached and maintained. With observed production rates ranging from 500,000 tons to 3,200,000 tons per year, 2,000,000 tons was selected as a representative average. This production level reflects an attainable production goal for a typical Western surface coal mining operation. From these basis assumptions, overburden removal rates were geared to meet coal production and detailed equipment and manpower configurations were generated. Computer simulations were employed to perform engineering and economic analyses of each concept. As with an actual mining system, each concept had physical limitations governing its potential application. Factors such as climatic conditions, overburden type and depth, and maximum working face height were evaluated for their constraint on the general applicability of each concept. Mining and reclamation costs were estimated for each system and compared with coal production rates. Discounted cash flow analyses were performed and tabulated for each concept. This provided a method for equitable comparison between concepts, even those designed for different terrain conditions.

This Final Report, presented in two documents (a summary volume and a detailed appendix), details all work efforts and data assembled during the course of this study. Descriptions of all pertinent information, recommendations, and conclusions are presented. Where appropriate, graphics have been employed to enhance the clarity of the material presented. The graphics used provide readily accessible, concise data compilations on concept parameters and are designed to enhance the utility of this report.



## CHARACTERIZATION OF PITCHING SEAMS

### UTILIZATION OF STATE MAPS

State maps, located in a separate appendix volume, have been chosen to graphically demonstrate those areas within the continental United States and Alaska which have coal fields or regions containing seams which meet the criteria (bituminous coal seams, dip ranging from 8° to 25°) of this study.

The large scale area map found on Figure 1 assigns each state an area number (Alaska 1 to Oregon 16) and depicts in a general way those states which have appropriately pitched coal seams recorded for them. For each state (area) shown on this reference map there is a detailed map with the regions or fields outlined upon it, and each is given an alphabetic three letter code. The first two letters give the state abbreviation, the third a code letter for that region or field which can be used to refer to the tabular data presented in the appendix. For example, WY-D is Wyoming - Hamm's Fork Region. Information on pitching coal seams in this region of western Wyoming can be acquired from the tabular data by either the name or by reference to the code letter. Conversely, the geographic location of information from the tabular data can be located quickly by reference to the Wyoming map region WY-D.

Within the regions shown on the state maps, single fields or regions are contained within a single boundary line. In the case of regions where all the contained fields have pitched seams, no subdivision of the region is attempted. For example, CO-A - The Uinta Basin of Colorado is shown undivided into its constituent fields, since all have pitched seams recorded. However, WY-B - The Big Horn Basin of Wyoming shows three subdivision lines for the only three coal fields, Hudson, Alkali Butte, and Pilot Butte which are the ones having appropriately pitched seams in that coal region. This practice of showing subdivisions of regions has been followed wherever there are a significant number of fields in a region which do not meet the criteria of this study.



**LOCATION MAP - PITCHING COAL SEAM AREAS  
OF THE CONTINENTAL UNITED STATES**

FIGURE 1

All the data presented on the state maps has been derived from published maps of coal fields or regions. In each case the most detailed or recent map has been chosen and the information required transferred to our base maps. The outline of the regions may have been somewhat generalized from the more detailed maps of total coal resources available. For some states, notably Alaska, the outline of a region in a relatively unexplored area - Northwest Arctic (AK-A) may be radically changed by further exploration, since all the interior of the region has not been adequately delineated. In some states where only one or a few data points exist there may be only a single county or portion thereof outlined on the state map. Counties were chosen as the third level in the hierarchy of reference for this study and it is best to limit the geographic presentation of the data when it cannot be extended to an entire field or region from published information. Bledsoe Co., Tennessee (TN-A), where only a single data point exists, has been limited in the map to that portion of the county surrounding the point. Also areas of Fayette and Somerset Counties in Pennsylvania (PA-A, PA-B) have been limited to clusters of points in those districts. Their inclusion under a single heading of the entire fields would be misleading.

**INDEX OF AREAS AND REGIONS HAVING  
PITCHING COAL SEAMS**

AREA	STATE	REGION/FIELD	ALPHABETIC CODE
1	Alaska	Arctic Northwest Region Susitna Field	AK-A AK-B
2	Washington	Bellingham Field King County-Renton Field Spiketon Field Centralia-Chehalis Field Kelso-Castle Rock Field Roslyn-Cle Elum Field	WA-A WA-B WA-C WA-D WA-E WA-F
3	Montana	Red Lodge Field	MT-A
4	Wyoming	Big Horn Basin Region Wind River Basin Region Sussex Field Hamm's Fork Region Hanna Field	WY-A WY-B WY-C WY-D WY-E
5	Utah	Coalville Field Wasatch Plateau Field Book Cliffs Field Kolob Field Vernal Field	UT-A UT-B UT-C UT-D UT-E
6	Colorado	Uinta Basin Region Green River Region North Park Field Denver Basin Region Canyon City Field Trinidad-Raton Region San Juan Basin Region Montrose Region	CO-A CO-B CO-C CO-D CO-E CO-F CO-G CO-H
7	New Mexico <sup>1</sup>	Gallup Field La Ventana Field Cerrillos Field Una del Gato Field Datil Mountain Field Carthage Field Sierra Blanca Field	NM-A NM-C NM-D NM-E NM-F NM-G NM-H

**INDEX OF AREAS AND REGIONS HAVING  
PITCHING COAL SEAMS**

<b>AREA</b>	<b>STATE</b>	<b>REGION/FIELD</b>	<b>ALPHABETIC CODE</b>
8	Oklahoma	Arkoma Basin Region	OK-A
9	Arkansas	Arkansas Valley Field	AR-A
10	Alabama	Warrior Field	AL-A
		Coosa Field	AL-B
		Cahaba Field	AL-C
11	Tennessee	Bledsoe Co. (Cumberland Plateau Region)	TN-A
12	West Virginia	Randolph Co.	WV-A
		McDowell Co.	WV-B
13	Virginia	Virginia District	VA-A
		Valley Fields	VA-B
14	Pennsylvania	Connellsville District	PA-A
		Meyersdale District	PA-B
		Broadtop Field	PA-C
15	Maryland	Castleman Basin Field	MD-A
		George's Creek Field	MD-B
16	Oregon	Coos Bay Field	OR-A

<sup>1</sup>NM-B was deleted after the map sequence was defined. No NM-B exists.

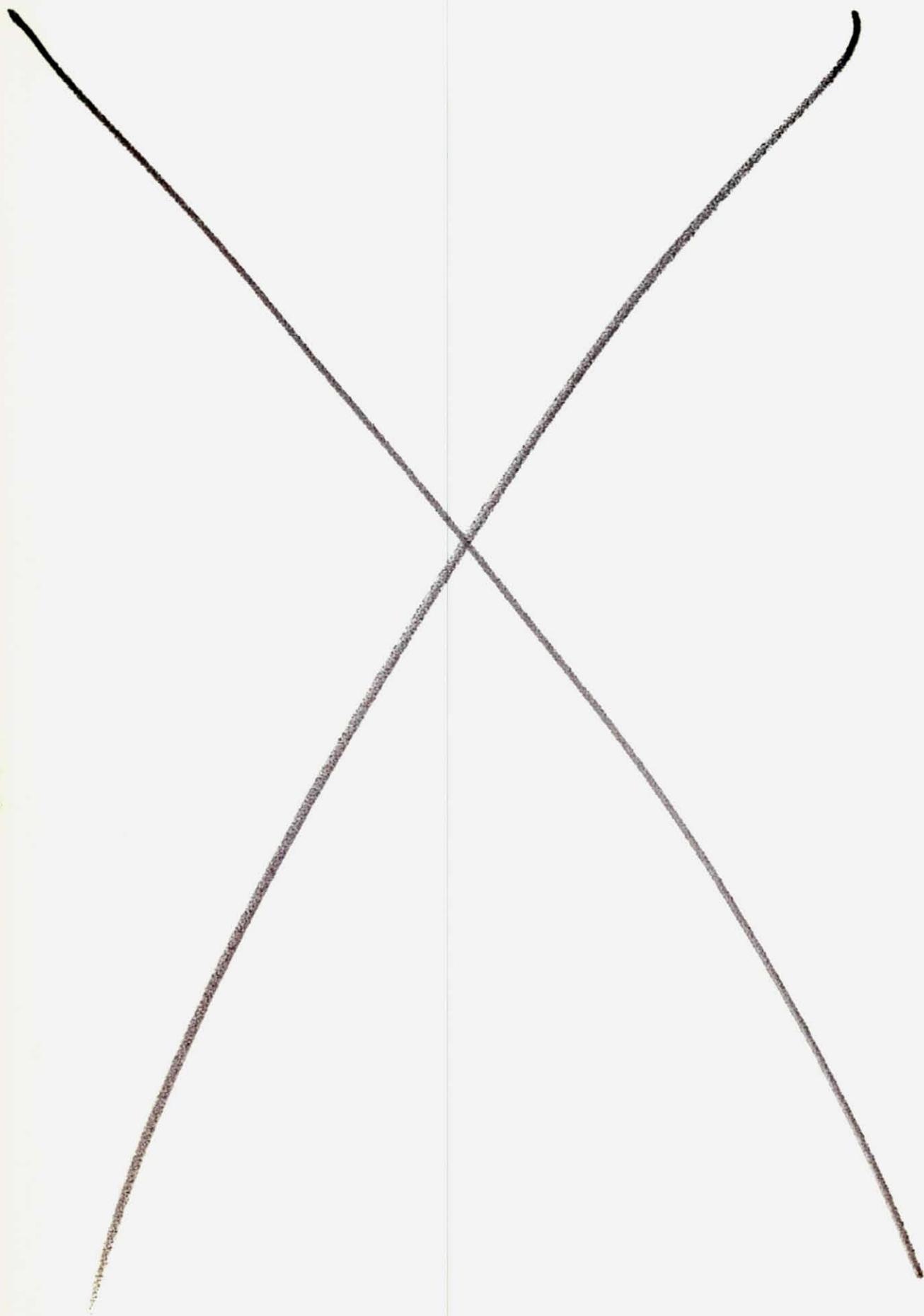
## UTILIZATION OF RESERVE CHARACTERIZATION CHARTS

The characterization charts in the appendix provide a comprehensive listing of moderately pitching coal seams in the United States. As discussed previously, base maps were developed from the compiled information. These maps illustrate the coal regions and coal fields where pitching seams occur. Contact was made with State coal geologists to refine and focus initial work efforts. The information provided was invaluable in filling data gaps and gave rise to a more thorough literature search. The extensive in-house library of Skelly and Loy was a vital source of information as were the United States Geological Survey and Bureau of Mines libraries in Denver. Additional reference materials were procured from several prominent mining education institutions.

In order to clarify the data, certain criteria had to be established. One was to prioritize a ranking system designed to maintain consistency. A system was set up as follows. In states where the extent of coal is large, regions are delineated (see Colorado, Area Six). Within these regions, fields are established; however, in some states the coal fields, not coal regions, were the largest subdivision (see Maryland, Area Fifteen). From this point, seam information was of prime interest. Once a seam was noted as falling within desired parameters (dip ranging from 8° to 25°), it became of major importance to locate the county in which it belonged. This information was necessary to provide accurate reserve estimates. When the situation arose that a seam had various names or occurred in several counties, these were denoted. An excellent example of this is the Clark Seam known also as the Blocton #1, Buck and Woodstock. It is found in both Bibb and Shelby counties of Alabama. Variation in pitch for each seam is listed with the available quality information following. The goal was to achieve the highest resolution at the lowest subdivision (county - field - region).

To accurately assess areal extent and reserve information, prioritization became absolutely fundamental. Under reserves, "S" and "T" represent strippable and total respectively and "n.a." refers to information not being available. Total reserve figures reflect coal lying in beds less than 3000 feet deep as this is generally considered the practical limit of recovery. Below this depth, ground bearing pressure becomes so formidable as to prevent even longwall mining. In cases where only total reserve information appears, it is probable that the seam was not strippable. Data from these seams generally were from underground mine operations. When reserve information was not available for a particular seam within a field, reserves were given for the entire field. This same rationale applied for areal extent. The ideal situation was to report the extent of a seam within a county; however, if this was not possible, the extent of the field was given. No attempt was made to quantify additional seam characteristics such as fault displacements or seam continuity. Although general trends do exist, such as faulting usually occurring in mountainous or uplift areas, these parameters are so site specific that they are beyond the scope of this project.

The abbreviations found under overburden characteristics are standard geological notations. A glossary delineating additional abbreviations is located in the appendix preceding the characterization tables.



## EXISTING PITCHING SEAM COAL MINES

The following sections present case history mines representative of moderately pitching coal seam operations within the United States. These case histories describe pertinent geographic, topographic, geologic and climatic conditions, in addition to discussions of mining unit operations and auxiliary functions. To enhance an understanding of the narratives, an artist's illustration depicting the mining scheme being employed at the mine site has been developed.

For each representative mine site, a complete economic analysis has been performed. Tables depicting manpower, equipment costs, capital requirements, depreciation schedules, annual operating costs and a discounted cash flow analysis (assuming a 15% return on investment) have been included for each case history mine. Although the majority of information used in the analysis was gleaned from data collected during the field study, in instances of data gaps regarding equipment and material costs, manufacturers' suggested retail prices were used. Additionally, to ensure comparability between the operations, all wages are those effective November 1977, in accordance with the Bituminous Wage Agreement of 1974. Since portions of the cost analyses do include costs generated through consideration of materials input, it should be understood that final results represent typical operations rather than exact reflections of the case study mines.

The following formulas and symbols were used with annual discounting tables to determine a coal selling price:

$$P = R \times \frac{(1 + r)^n - 1}{r(1 + r)^n}$$

R = total capital requirements

R = present value of P due in 20 years at 15% compound interest

$r = 15\%$

$n = 20$  years

Depletion = 10% of total sales not exceeding 50% of gross profit

Federal Income Tax = 50% of taxable income

Annual Cash Flow = net profit + depreciation and depletion

Coal selling prices reflect market values necessary to acquire a 15% return on capital invested at a particular operation. Although this is higher than the traditional 12% minimum return, present inflationary conditions necessitate 15% being a minimum. Some mining companies indicate a need for returns as high as 30%. Underlying factors include: lack of available capital; high interest rates; payment for large equipment prior to delivery; unknown final purchase prices on delivered equipment; escalating cost of operation supplies coupled with shortages; and uncertain impacts of new federal legislation.

Cost analysis procedures are standard U.S. Bureau of Mines techniques following the format outlined by I.C. 8661 "Basic Estimated Capital Investment and Operating Costs for Coal Surface Mines". Cost items estimated for capital requirements such as field indirect, overhead, and administration, contingency, and fee are standard percentages developed by a statistical analysis of the industry. All other capital parameters were provided by the mine operator. All operating expenses except for indirect and fixed costs were obtained either from manufacturers or the operators.

All detailed cost tables have been placed in the appendix volume of this report. However, summary tables have been incorporated into this volume with individual case history mine narratives.

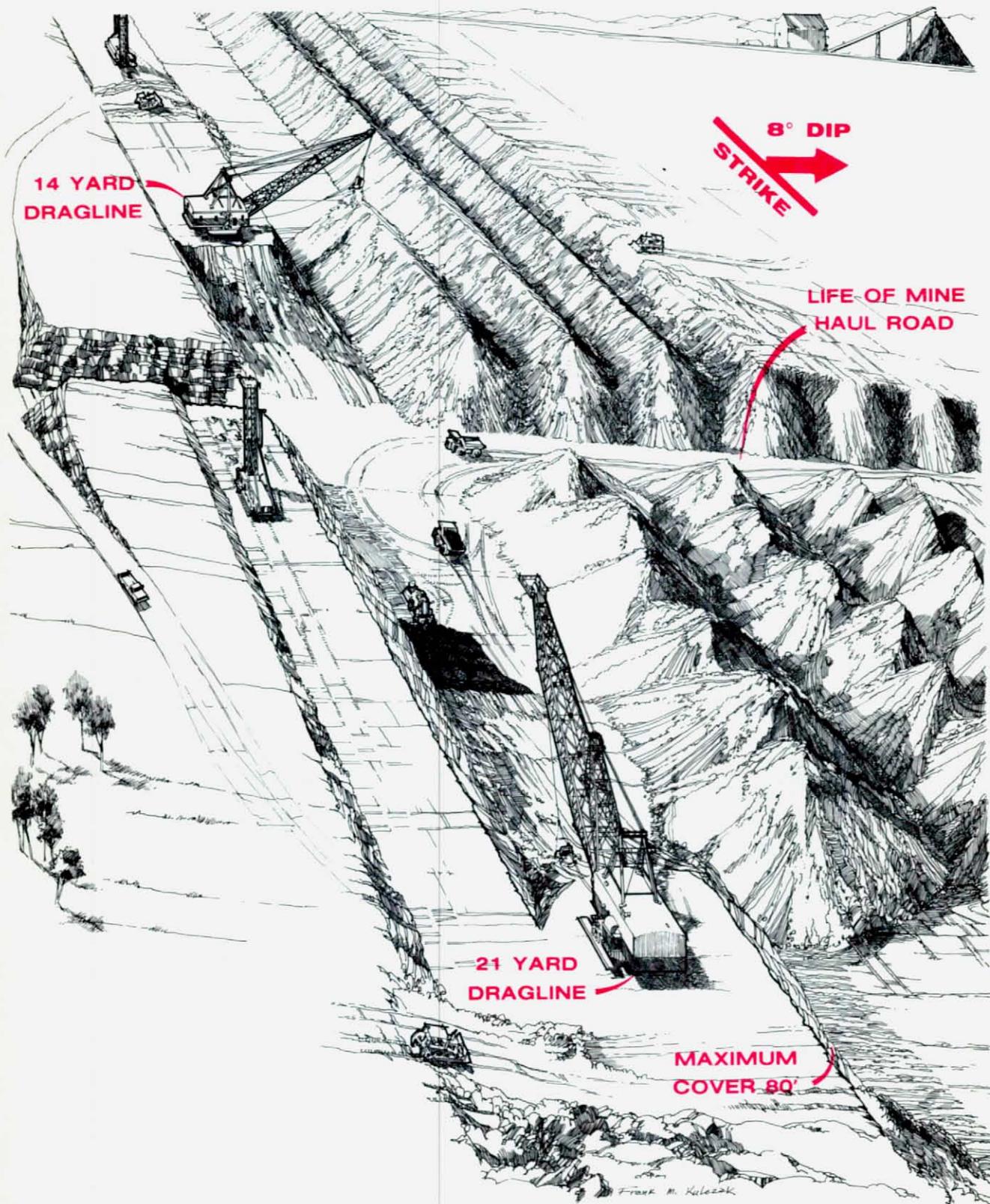
## CASE HISTORY MINES 1 AND 2

At this mine two separate pitched seam mining systems were evaluated. One was an opencast dragline system, strike-line mining up an 8° dip. The other was a front-end loader/shovel-truck haulback system, strike line mining down a 10° dip. To avoid repetition, we have summarized the area description and reclamation practices for both pits into one narrative. Unit operations and site specific factors are discussed separately.

These mining operations are located in Colorado, and lie along the eastern edge of the Yampa Coal Field. Local terrain is hilly with a series of north-south trending hogback ridges, the predominant terrain feature. Climate is typical of an interior basin with hot dry summers and cold snowy winters. Annual precipitation averages 14 inches per year, with over 50 percent occurring during the winter. These operations are geared to the extreme cold and frequent heavy snows and so are not usually affected by adverse weather.

The Wadge seam is being mined in both pits and averages 10 feet thick. Coal is sold on the steam market with 11,200 BTU's and 0.45 percent sulfur. Overall, the seam is consistent, but some fault interruptions have been encountered. One major fault, through the dragline pit, had a 30 foot displacement, but they were able to mine through the faulted area.

Geology in this area is dominated by the moderate dip of the coal bearing strata. Faulting is evident, but has not inhibited mining. In the dragline pit the coal dips at 8°. The coal dips 10° in the front-end loader/shovel-truck pit. Overburden consists of sandstones and shales with about 6.5 feet of weathered clayey material at the surface. Cover averages 60 feet thick on the flanks of the hogback ridges. Topsoil averages 2 feet thick and is stockpiled. There was no evidence of highwall or spoil stability problems at either pit.



Clearing and grubbing is generally done with D-9 bulldozers except when aspen stands are present. Some trees are removed for experimental transplanting; however, most are felled and windrowed. Self loading 18 cubic yard scrapers are used for topsoil removal and stockpiling. These operations are kept within 300 feet of the mining to eliminate or reduce erosional hazards.

At the dragline pit, D-9 bulldozers construct benches for the 9 inch Robbins drills. Holes are spaced on 18 foot centers with either 20 or 22 feet of burden. Blasting is done with ANFO loaded at 0.5 pounds per cubic yard of burden. Cast primers are initiated with cap detonated primer cord downlines. Standard practice calls for a 17 millisecond delay between holes. Instances of poor breakage and secondary shooting were observed.

Two draglines, with 21 and 14 cubic yard capacities, are the primary stripping units. Each dragline works along the strike of the coal from the center of the pit to the outer limit. The mine advances up-dip with spoil cast down-dip, thus the draglines are actually operating in a strikeline fashion. At the end of each cut the draglines deadhead about 8 hours to begin the next cut. Spoil rehandle is limited to a maximum of 5 percent. As depicted by the artist's illustration, each dragline begins excavating at a box cut which has been constructed as a life of mine haul road, roughly splitting the property and creating 1000' dragline strips. Keycuts are created and cast on the down dip side. The 21 cubic yard unit pictured on the lower right hand portion of the illustration possesses automatic cable braking, causing the uneven spoil piles depicted. While not a major problem it does cause some excess dozer time during reclamation.

Each dragline is benched down by a 400 HP dozer. This resulting overburden depth remains shallow enough to allow both units to operate in a typical open cut situation. However the top material plus the key cut spoil do lie against the low wall, resulting in some rehandle.

- ◀ FIGURE 2 - Artist's Sketch Illustrating Strikeline/Tandem
- ◀ Dragline Mining System Used at Case History Mine 1.

10° DIP



Coal is drilled, for shooting, on 12 foot centers with a 3 inch drill. A powder factor of 0.3 pounds of ANFO per ton of coal resulted in good fragmentation. A 20 cubic yard Le Tourneau front-end loader works both pits. Coal is hauled from the dragline pits, using 50 ton end dump trucks, and carried 1.7 miles to a storage/loading site. Overburden handling operations at this mine site are conducted seven days a week, three shifts a day. Drills and support equipment operate on a two shift, seven day/week basis. Coal loading consumes the least effort, operating one shift five days per week. Property constraints dictate the mining limit, thus cut-off stripping ratios play a minimal role in establishing mining limits. Disturbing approximately 180 acres per year, annual production approaches 3.2 million tons. With an average strip ratio of 6 to 1, mining costs come close to \$8.00 per ton.

At the front-end loader/shovel pit, 18 cubic yard self loading scrapers are used to stockpile topsoil and remove the initial weathered clayey overburden. Terrain and overburden characteristics permit the scrapers to be used for drill bench construction during their stripping activities. A 9 inch Robbins drill puts down blast holes on 18 foot spacing. ANFO, loaded at 0.8 pounds per cubic yard of burden, is the primary blasting agent. Detonation techniques and delays were the same as those at the dragline operation.

This is a two cut strikeline mining sequence employing a 10 cubic yard front-end loader and a 7 cubic yard electric shovel used for loading shot material. The stripping shovel is more than 15 years old, however, it is quite serviceable. Fifty ton end dump trucks are used for hauling all the overburden. Average haul distance, for the mine life, is 1500 feet one way.

Figure 3 illustrates the double cut system employed at this site. A 10 cubic yard front-end loader advances the cut containing the shallowest overburden (the up dip cut). Haul trucks carry material from the advancing face up a haul ramp, out of the pit, and along an edge of pit road to the reclamation area. A second cut, excavated with a 7 yard shovel, follows approximately 1500 feet behind the loader pit. The same edge of pit haul

- ◀ *FIGURE 3 - Case History Mine 2 -Strikeline*
- ◀ *Loader/Shovel Truck Haulback Operation.*

road is used by trucks utilized by this system's shovel. A total truck fleet of four haul rigs is divided between both stripping units.

A D-9 dozer with a Kelly ripper breaks the coal for loading. The 10 yard overburden front-end loader and its complement of trucks remove coal from both pits. About 40 percent of their total operating time is spent loading and hauling coal. A stockpile/loading point, independent of the dragline operation, is maintained about 1.2 miles from this operation. The rapid rate of pit advancement necessitates loading and hauling coal on the dipping pit floor.

Regrading at both sites is to approximate original contour. D-9 bulldozers are used to knock down spoil ridges and establish rough grade. A Raygo Giant, articulating grader, is used to establish final grade. Revegetation is done with a variety of native and introduced grass species. Experimental transplants of several native shrubs and trees are being tried. Erosion control is done with gradient terraces where conditions warrant. There are no water problems at these mines. Stripping limits at this minesite are determined by an economic stripping ratio cut-off. Final highwalls at this pit approach 110' resulting an average strip ratio of 8 to 1. Approximately 40 acres are disturbed on an annual basis. All operations except drilling and coal loading are conducted on a three shift/day, five day/week basis.

While the coal in this pit dips at only 10°, they are mining near the base of a small hill, and cover increases rapidly. An auger has been purchased to recover additional coal once the maximum highwall limit is reached. While detailed reserve information for this particular area was not available, a mining system utilizing larger overburden removal equipment could achieve higher coal recovery within the operating limits of the auger.

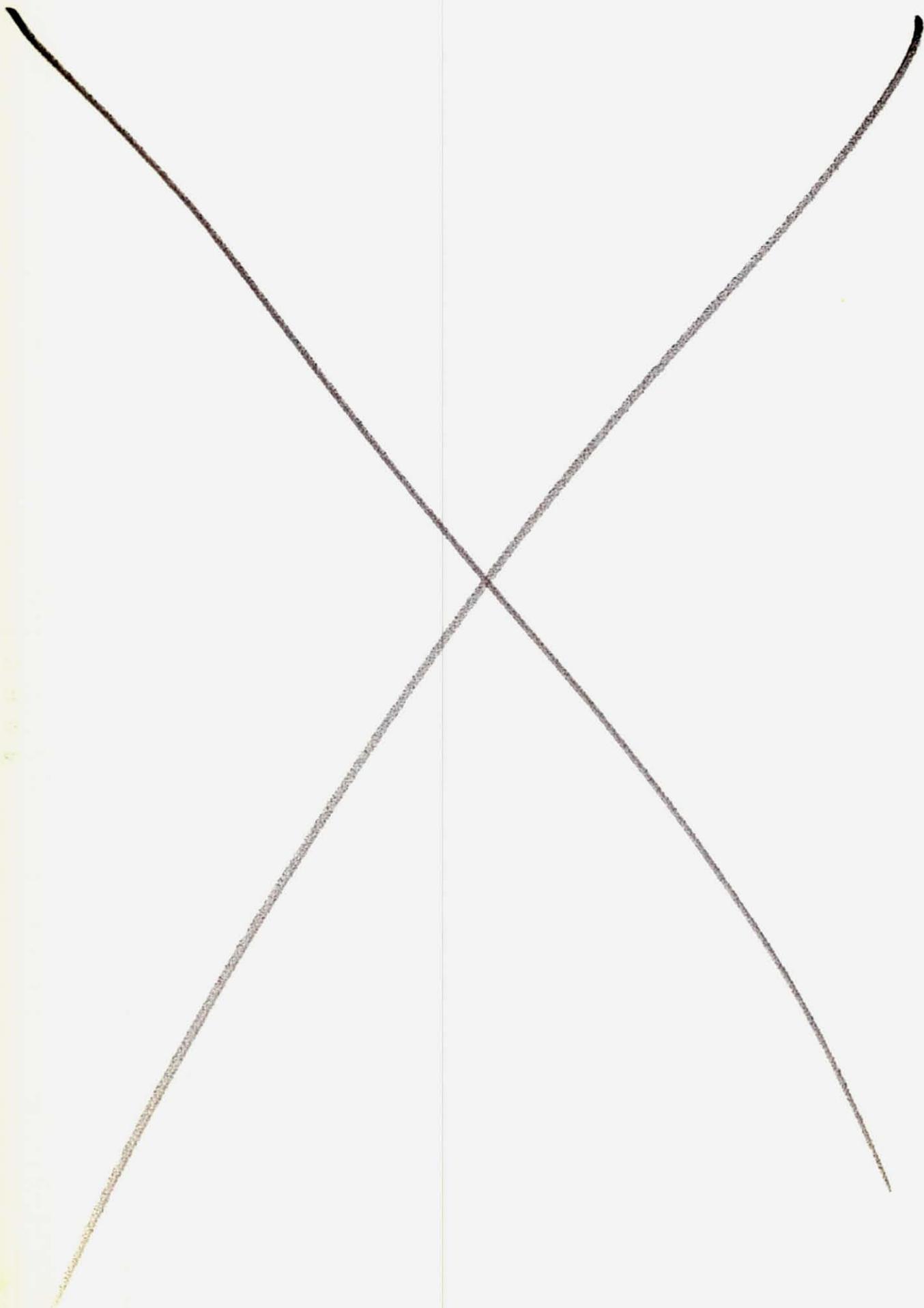
Both draglines are down 1 shift in 20 for maintenance. All other equipment is maintained on an "operating hours" basis. A main 69 KVA substation supplies power to portable substations. The 21 cubic yard dragline receives 7200 volts with 3100 volts delivered to the 14 cubic yard machine. Parts and supplies are kept in a well maintained warehouse facility with no special problem areas denoted.

**TABLE 1**  
**CASE HISTORY MINE 1 - ECONOMIC PARAMETERS**

<b>ANNUAL OPERATING COSTS</b>	
Manpower	\$ 3,460,000
Operating Supplies	5,540,000
Auxiliary Cost	9,494,000
Indirect Cost	1,350,000
Fixed Cost	425,000
Depreciation	4,096,000
<b>TOTAL ANNUAL OPERATING COST</b>	<b>\$24,365,000</b>
<b>ANNUAL COAL PRODUCTION</b>	<b>3,200,000 Tons</b>
<b>OPERATING COST PER TON</b>	<b>\$7.61</b>
<b>DISCOUNTED PRICE PER TON (15%)</b>	<b>\$8.78</b>

**TABLE 2**  
**CASE HISTORY MINE 2 - ECONOMIC PARAMETERS**

<b>ANNUAL OPERATING COSTS</b>	
Manpower	\$1,424,000
Operating Supplies	1,980,000
Auxiliary Cost	1,819,000
Indirect Cost	511,000
Fixed Cost	129,000
Depreciation	1,411,000
<b>TOTAL ANNUAL OPERATING COST</b>	<b>\$7,274,000</b>
<b>ANNUAL COAL PRODUCTION</b>	<b>500,000 Tons</b>
<b>OPERATING COST PER TON</b>	<b>\$14.55</b>
<b>DISCOUNTED PRICE PER TON (15%)</b>	<b>\$16.93</b>



### CASE HISTORY MINE 3

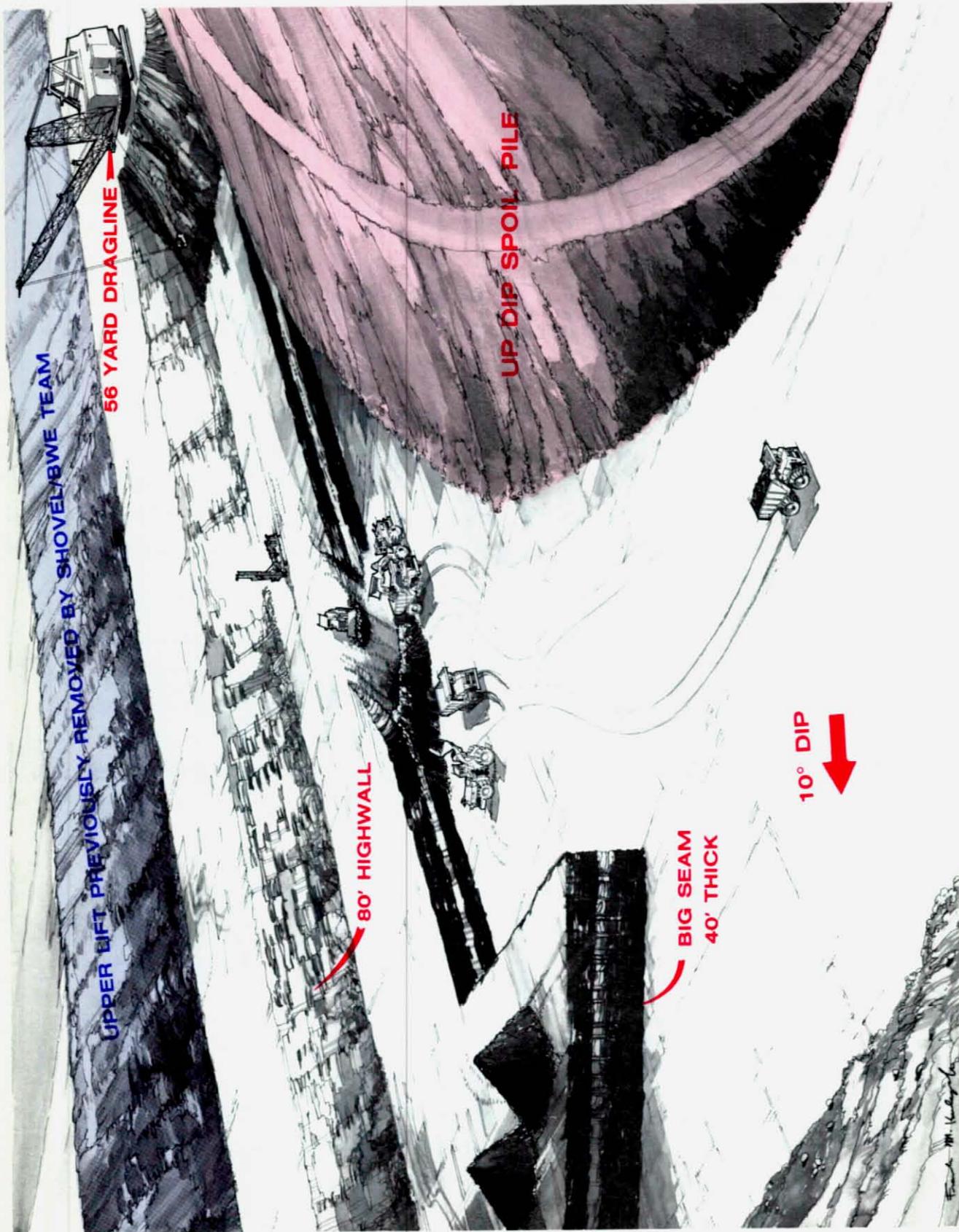
Located in southwestern Washington, this mine falls within the Centralia-Chehalis Coal Field. The Big Seam (Big Dirty) is mined. Local terrain consists of rolling hills and flat alluvium filled valleys. Valleys in the immediate mine vicinity are peat-filled and very unstable to loading. This area has a coastal climate with annual precipitation averaging 48 inches. Over 50 percent of the yearly precipitation occurs from November through February.

At this mine, the Big Seam averages 40 feet thick, however, there is a 25 percent refuse loss. All coal produced is sold under a "captive contract" to a local electric generating station. Cleaned, as received at the plant, this coal has 8,100 BTU with less than 0.5 percent sulfur. Several volcanic ash layers (clay bands) and other impurities are evident in this seam and appear to be continuous throughout the property.

Geology throughout the Centralia-Chehalis Coal Field is complex. There is a great deal of faulting, but generally, displacements are not great enough to interrupt mining. Coal dip within the mine area ranges from 8 to 16 degrees with an average of 10 degrees. Overall, coal thickness is consistent, but several washouts have been encountered. Overburden consists of shales and friable sandstones with intermittent volcanic ash layers.

Spoil stability problems led to the implementation of a down-dip diagonal mining system. Spoil slides during the initial attempt at strike-line mining necessitated the change. The diagonal mining system has been working quite well.

Timber removal is contracted to a logger, who also does some of the clearing and grubbing. Non-commercial timber, stumps and vegetative ground cover are windrowed and burned. These operations are kept as close to the mining as feasible to prevent erosion. All areas are



UPPER LIFT PREVIOUSLY REMOVED BY SHOVEL/BWE TEAM

56 YARD DRAGLINE

80' HIGHWALL

UP DIP SPOIL PILE

10° DIP

BIG SEAM  
40' THICK

Frank M. Kelly

cleared, but as they are scheduled to sit idle for two months or longer, seeding is required to reduce erosional losses. Topsoil is removed just prior to mining, but it is not stockpiled and is regraded into the overburden. Deeper strata have high nutrient levels and are a very good plant growth medium. Additionally, this operation is working toward agricultural reclamation. By not using topsoil, weeds are eliminated, and subsequent wheat crops are "seed quality" with a substantially higher market value.

High precipitation and soil erodibility combine to necessitate well designed and maintained haulage and access roads. All roadways are well engineered for drainage control. However, even the use of large amounts of road aggregate does not completely prevent "soupy" conditions during rainy periods. Road design and maintenance permit normal operations even during extended rain. Road maintenance costs were reported as averaging \$0.40 per ton of coal mined.

At the time of this mine evaluation, this operation was in the final months of production. During earlier phases of pit development, scrapers, shovel-truck combinations, and a bucket wheel excavator-conveyor unit were used for overburden removal on the upper lift. The final mining plan utilized a 56 cubic yard dragline for overburden stripping and two front-end loader-truck teams for coal loading and haulage.

D-9 dozers are used to construct drill benches for the 9" Robbins overburden drill. Blasting operations are carefully engineered and monitored to avoid highwall stability problems and other site specific considerations. Drilling patterns vary with each operation. For normal excavations a 30 foot spacing and burden are used. The dragline bench keyway cuts are shot with 30 foot spacing and 40 foot burden, but over the coal 40 foot spacing and burden is used. An average powder factor of 0.3 pounds per cubic yard of burden is utilized, however, this varied from 0.23 to 0.5 depending upon strata characteristics. As mining operations approached the valley floor, the detonating sequence was changed from parallel to the highwall face to perpendicular to the highwall face. This was done to prevent cracks from extending beyond the end of the pit and into

- ◀ FIGURE 4 - Artist's Rendering, Depicting Case
- ◀ History Mine 3 - Diagonal Dragline Scheme.

the valley floor strata. Because the valley material was saturated, it was felt that any cracks into the valley fill material could result in inundation of the working pit.

At this stage of the operation, all of the remaining overburden is to be removed by a 56 cubic yard dragline and cast on the up-dip side. Overall, approximately 50 percent of the total overburden in place was handled in this way (upper 50 percent removed by combination shovel/BWE). The dragline is currently operating on an extended bench sequence that necessitates between 75 and 100 percent rehandle on a bank cubic yard basis. This rehandle is caused by the spoil material falling into the active pit due to the dip of the coal. This is one of the drawbacks of casting overburden on the updip side. Although at some operations a small coal fender is left unmined to hold back this sloughage, the thickness of the coal at this site merits a rehandle operation. Pit length varies with geology and dip, but the dragline uses only 0.6 percent of its available operating time, deadheading at the end of each cut.

Coal is broken for loading using a D-9 bulldozer with a Kelly ripper. For economic reasons and better fragmentation control, they are experimenting with coal blasting. Current experiments are done with 9 inch holes drilled on 25 foot centers, with plans to go to 6 inch blast holes. Two 18 cubic yard front-end loaders load into 100 ton end dump trucks. Usually, three to five trucks are assigned from the fleet to haul out of this pit. The haul ramp out of the pit was just over 2,100 feet with the initial 500 feet at ten degrees, and the remainder at approximately six degrees.

Because the mine was advancing diagonally down the 10° to 12° dip of the coal, haulage was ramped 2,100 feet out of the lower end of the pit at an average grade of 6°. The central haulage ramp was maintained by mining alternate sides of the property. This technique reduced the length of each dragline cut and subsequent deadheading time. Overall, this diagonal mining system was well engineered and operated efficiently.

With the possible exception of the final pit, regrading is done to approximate original contour with final slopes gentler than the previous land surface. The gentler slope helps prevent erosion and enhances the use of farm machinery during post mining agricultural activities. Scrapers and D-9 bulldozers are used to establish final grade.

Revegetation at this mine is a complex planning process. Various site factors are evaluated to determine final land use. On suitable areas, agriculture is the post mining land use for at least three years. Other areas are seeded to rye or wheat for briefer periods. Plans call for reforestation on a substantial part of the area, but this is not projected for full implementation for several years.

Stripping limits at this site are always constrained by property boundaries and not economics. With an average stripping ratio of 5 to 1 every attempt is made to maximize coal recovery. Dragline excavation is carried out at the mine on an eight hour shift, three shift per day, six day per week schedule, all other auxiliary functions are operated two shifts, five days per week. Area disturbed per year converges on fifty acres.

Water handling and treatment are major considerations at this operation. High rainfall and frequent high intensity storms necessitate efficient erosion control and water treatment systems. On regraded areas, gradient terraces, sloped at one percent, are used to carry runoff to rock lined channels and then to the ponds. A two step flocculation system is used to remove colloidal clays and achieve the required water quality.

Equipment maintenance is scheduled on an operating hours basis with the dragline being serviced at each "lunch period". Roadways are constantly maintained by adding road aggregate, grading, or watering as conditions dictate. A fairly complete parts and supplies inventory is maintained at the mine. The only problem area was acquiring large dragline/shovel parts. A 25,000 KVA main substation supplies power to the 7,500 KVA portable substations at each pit. A 350 MCM cable delivers 6,900 volts to the dragline.

Climate in the vicinity of this mine is characterized by high annual precipitation and frequent high intensity or long duration rainfall events. Water accumulation at the coal loading face and reduced haulage efficiency were the most noticeable problem areas. The central haul ramp seemed to channel runoff directly into the pit, and at one point 4 to 6 feet of water had accumulated at the loading point. While the 18 cubic yard Dart loaders and 100 ton haulers were not significantly affected, the potential exists for water accumulation significant enough to necessitate cessation of coal loading.

**TABLE 3**  
**CASE HISTORY MINE 3 - ECONOMIC PARAMETERS**

<b>ANNUAL OPERATING COSTS</b>	
Manpower	\$ 2,780,000
Operating Supplies	6,146,000
Auxiliary Cost	7,107,000
Indirect Cost	1,339,000
Fixed Cost	711,000
Depreciation	4,433,000
<b>TOTAL ANNUAL OPERATING COST</b>	<b>\$22,516,000</b>
<b>ANNUAL COAL PRODUCTION</b>	<b>2,330,000 Tons</b>
<b>OPERATING COST PER TON</b>	<b>\$9.66</b>
<b>DISCOUNTED PRICE PER TON (15%)</b>	<b>\$12.16</b>

## **CASE HISTORY MINE 4**

This mine is located in Colorado along the eastern edge of the Yampa Coal Field, a subdivision of the Green River Coal Region. The mine property lies at an elevation of 7,500 feet in generally hilly terrain dominated by a series of north-south trending hogback ridges.

Coal mined occurs in the Williams Fork Formation (Mesa Verde Group). Generally, the geology of the mine site is dominated by the gentle dip of the coal and coal bearing strata along the west face of a hogback ridge and extending down slope to Trout Creek. Dips, where the coal is mined, range from 8.5 to 12 degrees to the north and slightly west. Sharp folds and large faults do not occur within the mine area. There are common faults of 2 to 3 feet displacement, and one larger reverse fault, with a 15 foot vertical displacement, was recently encountered.

Coal mined at this mine comes from two different seams. The major seam mined at present is the Wadge, about 6 feet in thickness under an average of 65 to 70 feet of cover. This coal is primarily marketed as steam or industrial coal with an average BTU rating of 10,800 and sulfur content of 0.5%. The Wadge Coal is of consistent thickness and without significant partings. Coal from the higher Lennox seam is occasionally taken and prepared as stoker coal for the home heating market. Present operations encounter old underground workings which date into the 1940's or earlier, but these do not cause a significant reduction in mine output.

Topsoil averages two feet in thickness, and is of a light brown or buff color typical of drier mountain basin or slope soils under grass cover. Overburden is mainly a moderately coarse yellow to buff friable sandstone with some shale layers to two feet in thickness. The overburden material seems to pose no special difficulties, and spoil and highwall stability is good.



The climate is typical of an interior basin with hot dry summers and cold snowy winters, with an average precipitation of 14 inches per year. Temperatures may range from the high nineties in summer to extremely cold, below zero, highs in mid-winter. Extreme cold may hamper mining equipment and operations but these conditions are expected and seem to be met by the mine personnel.

Site preparation consists of timber removal where the mine will extend into areas covered by aspen stands. Generally, however, the area to be mined is covered by grasses and sagebrush only. Therefore, topsoil removal and stockpiling are the primary site preparations required. Haul and access roads have been constructed with a life of the mine expectancy. Roads are constructed with dozer, scraper, and grader. An estimated two weeks are required to construct 1,000 feet of roadway.

Clearing and grubbing are conducted year round with a dozer one shift per day. Usually clearing and grubbing are kept one to one and a half years in advance of mining. Topsoil is removed and segregated using a pair of Cat 637 self loading scrapers. Topsoil is hauled up to one half mile and stockpiled. Due to adverse weather conditions topsoil removal is intensively practiced only between mid-May and November. Topsoil is replaced evenly. Areas from which no soil was taken are covered by distributing that available from stock.

Overburden is drilled using a Bucyrus-Erie 40-R drill with a  $7\frac{3}{8}$  inch bit in two operating shifts per day. Drill patterns vary depending upon hardness of the overburden but are generally about 20 feet by 30 feet and up to 60 feet in depth. ANFO with gas primers or primer cord is the explosive used. Loading averages 10 to 20 pounds of ANFO per foot of hole depth. Each hole in a single line has a 17 millisecond delay with a 42 millisecond delay between lines. Wet holes did not seem to be a common problem but mine personnel did mention that slurry is used when excessive water was encountered.

- ◀ FIGURE 5 - Case History Mine 4 - Dipline
- ◀ Dragline Mining System.

As illustrated by the artist's drawing, mining at the operation is accomplished with a Bucyrus-Erie 1260 40 yard dragline excavating in a typical dipline area fashion. Cut advancement is up the dip with overall mine progression following a strikeline trend.

After blasting, the upper material to the Lennox seam is removed with the dragline and occasionally this seam is mined, stockpiling the coal on the highwall side. Remaining material is removed and cast in the opposite direction in a conventional area fashion. A slight amount of rehandle (11%) is experienced at the site due to the deeper cover (slightly beyond the dragline's open cut digging depth) and key cut material. Operating up-dip as is shown, little sloughage occurs from the spoil rows, keeping this rehandle to a minimum.

The pit advances up the 10° dip with the dragline deadheading 8,000 feet at the end of each cut. Coal haulage out of the pit is accomplished using two haul roads: 1) at the lower end of the pit and 2) about midway up the pit. While deadheading a 40 cubic yard dragline 8,000 feet incurs a considerable expense, the mine operator feels that coal haulage and pit drainage considerations offset the additional costs. By utilizing the existing system, all loaded coal trucks run out of the pit and then proceed up the hill to the dump point. On the lower half of the pit this involves "going the long way around", however, when road construction costs are compared with haulage costs over an extra 2,000 to 3,000 feet, the economics favor the longer haul.

The Wadge seam requires blasting. For this a Walden twin masted Porta-drill is used with a resulting pattern of two lines of 2<sup>3</sup>/<sub>4</sub> inch holes based on 12 foot centers. Blasting is with ANFO using Herculon primers. Coal loading is accomplished with a 9 cubic yard Bucyrus-Erie 88B diesel coal shovel. Coal spilled in the load area is retrieved from the pit floor by an 834 rubber tired dozer which is alternately used on final clean up of the coal surface after overburden removal. Coal is hauled to the conveyor hopper is a mixed fleet of four 50 ton and five 35 ton trucks traversing a one way distance of 2<sup>1</sup>/<sub>2</sub> miles against an average grade of 6<sup>1</sup>/<sub>2</sub>%.

Regrading is conducted on a year round basis except during exceptionally heavy snow cover periods. Dozers and scrapers are used for backfill and highwall reduction to the contour required. Revegetation is a company planned and directed project overseen by a reclamation foreman responsible for all phases of the work. Due to the variable climate, revegetation is limited to two periods, late spring and early autumn. Revegetation is accomplished at present using a mixture of native and range grass seed at 35 to 40 pounds per acre broadcast. Potash-nitrogen fertilizer at 700 pounds per acre is used. Some experiments have been attempted to establish aspen but these have been of limited success. Some areas have required reseeding and close attention is paid to periodic cover maintenance. There are, at present, three experimental plots managed by state agencies, two for tree regeneration and one for grasses, in progress on the mine.

The existing coal haulage system allows reclamation to progress with mining. Periodic disruption of regraded/revegetated areas by haul road development as the pit progresses is eliminated. One other consideration favoring this up-dip mining system is pit drainage. While for most of the year this is a dry operation, spring snowmelt runoff can concentrate a considerable amount of water in the pit. By constantly operating up-dip, water does not accumulate at the working face where it could impede operations.

The management of the mine attempts to keep sufficient maintenance facilities and parts inventory to accommodate repairs to the majority of the equipment in use. The facilities are a modern maintenance shop-warehouse and a separate electrical shop. Preventive maintenance is closely scheduled on an operating hours basis. Specific parts requirement problems have been encountered in limited areas but these are attributed to local dealership supply problems.

The MSHA health and safety regulations are strictly enforced and the mine management has an active, vigorous program to improve the use of safety equipment. The primary site specific health problem is dust

suppression. Due to the dryness of the area more man-hours and equipment are devoted to water application than in wetter areas of the United States.

The electrical distribution system is based on a 6900 KVA substation with 3400 KVA distributed to the dragline and 2500 KVA to the shops. Portable substations are used but only rarely moved.

**TABLE 4**  
**CASE HISTORY MINE 4 - ECONOMIC PARAMETERS**

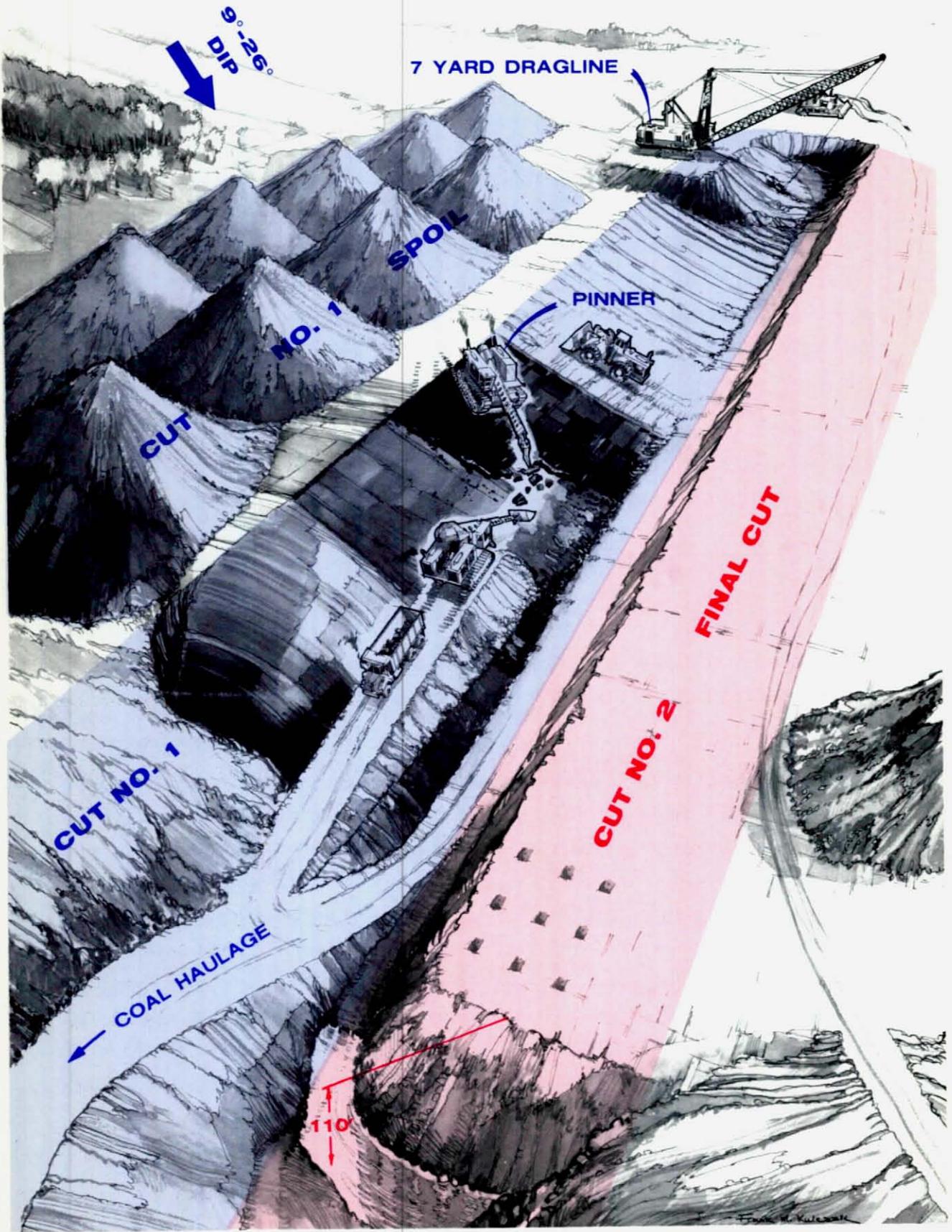
ANNUAL OPERATING COSTS	
Manpower	\$ 1,830,000
Operating Supplies	3,658,000
Auxiliary Cost	3,857,000
Indirect Cost	823,000
Fixed Cost	346,000
Depreciation	2,325,000
<b>TOTAL ANNUAL OPERATING COST</b>	<b>\$12,839,000</b>
<b>ANNUAL COAL PRODUCTION</b>	<b>1,200,000 Tons</b>
<b>OPERATING COST PER TON</b>	<b>\$10.70</b>
<b>DISCOUNTED PRICE PER TON (15%)</b>	<b>\$13.06</b>

## **CASE HISTORY MINE 5**

Located in Oklahoma, this mine falls within the Bokoshe Coal Field. Both the Upper and Lower Hartshorne seams are mined. Local terrain generally consists of low ridges, capped with resistant sandstone, and broad, gently sloping valleys. Climate is characterized by hot humid summers and cold humid winters. Annual precipitation averages about 40 inches with over 50 percent occurring from March through June.

At this mine, the Upper Hartshorne seam averages 30 inches thick, and the Lower Hartshorne averages 36 inches thick. Coal from both seams is sold on the metallurgical market, with "as received" BTU's at 14,500, sulphur of less than 1 percent and 5 percent moisture. A pyritic, boney middle band separates the seams over the entire operation. Portions of the Lower Hartshorne seam have been deep mined, primarily in the vicinity of the active pit. Old mine voids are fairly limited, however, coal recovery has been affected. Lower coal tonnages, hazardous conditions, and clean up problems (old timbers and rails) have affected the operation, but not to a marked degree.

Geology throughout the Bokoshe Field is highly complex. Generally, dips range between 9 and 26 degrees, with localized dips approaching 70 degrees not uncommon. At this site the Upper and Lower Hartshorne seams have been locally folded and faulted. As a result, dips in the active pit range from 23 to 70 degrees. In one fairly limited area the coal dipped 70 degrees down the lowwall side, climbed the highwall face at nearly 90 degrees before going under cover again at a gentler dip. Both seams tend to pinch out occasionally. The complex geology has not allowed the development of a set mining plan. Modifications are made weekly, daily and often hourly. Overburden consists of soft shales and mudstones overlain by 3 to 5 feet of unconsolidated soil material with an 8 to 12 inch 'A' horizon.



Severe dips, property size and shape, and the limited digging depth of the 7 cubic yard dragline has led to the utilization of a two lift strike-line mining system at this mine. Overall, this system works quite well and is easily modified to adapt to changing seam characteristics and areas where the lower seam has been mined. The dip has necessitated the use of modified coal removal equipment that will be discussed later.

Timber removal, clearing and grubbing are minor operations. Scattered patches of scrub timber and a gently sloping ground surface have reduced the effort required for these operations. Vegetative material is either windrowed and burned or buried in the final pit. Caterpillar D-9 bulldozers are used for clearing and grubbing. They can usually prepare two to three acres per day. One haulage and access road was constructed. Because a right-of-way across adjoining Federal land was denied, the haul road had to be constructed with negative grades in both directions. Road aggregate is not utilized and the clayey road surface, out of the pit, does become slick enough to curtail, and sometimes halt, coal haulage.

Topsoil removal and stockpiling is accomplished with 18 cubic yard self loading scrapers. Stockpiling of topsoil is done as close to the mine as possible on the up slope side. This is done to facilitate replacement of the topsoil using dozers and scrapers.

A Falling drill is used to put down 6½ inch blast holes for overburden shooting. Drill benches are not constructed because the terrain allows drilling on the level area created by topsoil removal. Generally an 18 x 18 foot drilling pattern is used with a loading of 300 pounds of ANFO per hole in the longer holes. Delays between holes are utilized, however, the delay pattern varies with loading and area being shot. Dynamite primers and primer cord downlines are detonated with blasting caps at the top of each hole. Blasted overburden was well fragmented and had a size range up to 30 inches. There were occasional larger pieces, but nothing beyond the dragline's capabilities was observed. There was no evidence of overshooting or flyrock.

- ◀ FIGURE 6 - Exhibit Depicting Case History Mine 5 -
- ◀ Strikeline Dragline/Scraper Haulback Mining Approach.

Approximately 75 percent of the overburden is removed with a 7 cubic yard diesel dragline operating two 9 hour shifts per day. First cut overburden (sequence shown on the artist's drawing) is cast on the up slope side of the pit. This has caused one spoil slide in an area where the coal and underlying strata were steeply dipping. Second cut spoil is cast to the down dip side. Because this area is at the base of the slope no stability problems have developed. Two 18 cubic yard scrapers are used to remove and stockpile topsoil, as well as remove second cut overburden below the dragline's digging depth. Overall this amounts to about 25 percent of the total overburden and utilizes 50 percent of the scraper's available time. The scraper's flexibility enhances coal recovery, especially in the first cut. Coal dip and the digging capabilities of the dragline result in a wedge of overburden and coal at the base of the first cut highwall. The scrapers are used to remove the overburden and increase total coal recovery. Because the coal is dipping at about 22° and the primary stripping unit is a 7 cubic yard dragline, the economic mining limit is reached in two cuts. Even though the scrapers remove overburden below the dragline's reach, a third cut is not possible. Areal extent and configuration of the land and mineral holdings are an additional constraint at this site. However, they do meet or exceed their production goals and operate at a profit.

If this mining system were modified to include total, or at least a higher percentage of overburden haulage, total recovery of their available reserves could be realized. A limiting factor would be the availability of an area suitable for storing the pit development spoil in an engineered fill. Local terrain conditions should allow adequate storage within economic haulage limits. Once initial pit development was completed, the spoil could be backstacked directly into the mined out pit. Spoil stability problems would be eliminated, and resource recovery enhanced, even within their narrow land ownership constraints.

To modify the current system to a more equipment intensive haulback operation would significantly increase both capital expenditures and premining and operational engineering costs. Improved productivity

and the recovery of an additional 50 percent of their current production should offset additional costs. The coal mined at this site is a high quality metallurgical grade product. This valuable resource should provide an adequate base for a higher recovery modification to the current system.

A small 5 cubic yard front-end loader is used to clean the coal surface prior to loading. Coal removal is accomplished with two pieces of equipment modified to operate efficiently on the varying pitch of these seams. A modified Gradall is used to break up the coal for loading. This machine is referred to as a "pinner" and consists of a Gradall body and boom mounted on the drive unit of an Army surplus tank retriever. The tread and idler system of the tank retriever gives a larger contact area between the tread and the coal. This increased contact allows the pinner to operate on the dipping coal with little or no slippage. A lightweight Kelly ripper tooth is attached to the end of the Gradall boom. The crowding action of the boom provides sufficient breakout force to fragment the coal. Additionally, the operator has enough control to leave the middle band intact, resulting in a very clean product.

A conventional track mounted Gradall, with a front-end loader type bucket reversed on the boom, loads the broken coal into two 15 ton end dump trucks. This Gradall is well suited to loading out pitched seams. The rotational capability of the boom allows the operator to match the bucket angle to the dip angle of the coal-middleband interface, thereby avoiding dilution of the coal. Truck spotting is not a problem because of the 360 degree swing of the Gradall. However, the 1½ cubic yard capacity of the coal loading bucket does increase the loading time. While this would be a definite constraint at a higher production goal, this operation meets or exceeds the market commitments for both quality and quantity.

Regrading is done to approximate original contour, however, coal removed does not fully compensate for the overburden swell factor. D-9 dozers are used to push the spoil material into the mined out pit from both sides. The scrapers augment the dozers by replacing both spoil and topsoil to the mined area. Final grade is established with dozers.

Revegetation was not a major item. Soil samples are sent to the local Soil Conservation Service office for analysis and seeding recommendations. Seed mixtures vary with the season. Reseeding is done by a contractor following the Soil Conservation Service's recommendations. Reclamation objectives are primarily the establishment of grass stands suitable for grazing. Tree planting has been specifically excluded from the reclamation plan by the land owner. Approximately 50 acres per year have been reclaimed. Annual production approximated 80,000 tons a year, resulting in a fifty-five acre disturbed area. As mentioned previously, two cuts are the economic limit at this minesite, culminating in a 110 final highwall.

No water problems, outside of periodic rainfall accumulation in the pit, were observed. Pumping, even for storm runoff, was not required.

Equipment maintenance was performed on an "operating hours" basis with a rotation system on mobile equipment. Generally, there were no "parts and supplies" problems, with the exception of "small parts" for the Gradalls. Health and safety considerations were those required by existing regulations and non-specified factors dictated by geology and common sense.

**TABLE 5**  
**CASE HISTORY MINE 5 - ECONOMIC PARAMETERS**

ANNUAL OPERATING COSTS	
Manpower	\$ 600,000
Operating Supplies	797,000
Auxiliary Cost	438,000
Indirect Cost	210,000
Fixed Cost	65,000
Depreciation	466,000
 TOTAL ANNUAL OPERATING COST	 \$2,576,000
 ANNUAL COAL PRODUCTION	 80,000 Tons
 OPERATING COST PER TON	 \$32.20
 DISCOUNTED PRICE PER TON (15%)	 \$39.20

## **CONCEPT DEVELOPMENT AND EVALUATION APPROACH**

### **CONCEPT GENERATION**

Utilizing data collected during the field study, evaluations of operational problems associated with pitching seam operations were made. From these analyses, design criteria were formulated to aid in developing improved extraction methods for use in moderately pitching seams. A production goal of 2 million tons per year was established as typical of pitching seam operations. Other design guidelines included: compliance with all aspects of both State and Federal mining regulations; haulroad grades were limited to 8 - 10° as a maximum; where coal haulways could not be maintained at less than 10°, conveyor haulage was considered; down-dip dragline spoiling was desired where feasible; and equipment selection was limited to readily available equipment. Information obtained from mine operators and equipment manufacturers indicates that exceeding an 8 - 10° haulage grade adversely affects haulage costs by reducing cycle times and adding to equipment maintenance costs. Field investigations also revealed implementation of down slope dragline spoilage to be an effective means of controlling in-pit dilution and maximizing the open-cut excavating capability of any dragline.

At this point, engineers, geologists and mining technicians began conceptualizing techniques that met the necessary criteria. These initial concepts were carefully scrutinized to weed out those methods which demonstrated little potential. Additionally, in some instances, features of one technique were blended with promising aspects of another. The end result of this task brought to light six (6) potentially viable concepts which were then subjected to an intense engineering and economic evaluation.

## **REPRESENTATIVE MINE SITE**

To accurately assess the production capability of the proposed mining scenarios, a representative mine site was developed. Plans and cross sections of a potential pitching seam area were drafted and standard earthwork computations were performed. Each concept was applied to the mine site so that production rates and operation parameters could be determined.

The representative site chosen for this study contains a coal seam pitching approximately  $10^\circ$  with the surface slope dipping opposite the coal seam at  $8^\circ$ . Both single and multiple seam configurations were utilized in the evaluation process. For the single seam scenarios a coal thickness of 18' was assumed and an average strip ratio limit of 4 bank cubic yards per ton of coal was established. This resulted in a maximum highwall of approximately 150' for all concepts. To illustrate multi-seam mining scenarios, the typical site was altered to contain additional pitching seams ranging in thickness from 4' to 24'. Since the key parameters in a comparative evaluation of alternative mining approaches revolve around overburden handling and in-pit coal removal procedures, haulage to the preparation facilities or market was not factored into economic analyses. While this site is not an ideal situation, it was chosen as a "worst case" mine site in an attempt to bring out operational problems associated with the concepts that might not surface under close to ideal conditions. Additionally, using a site of this nature, alternate configurations could be evaluated by slightly varying the surface and coal dip.

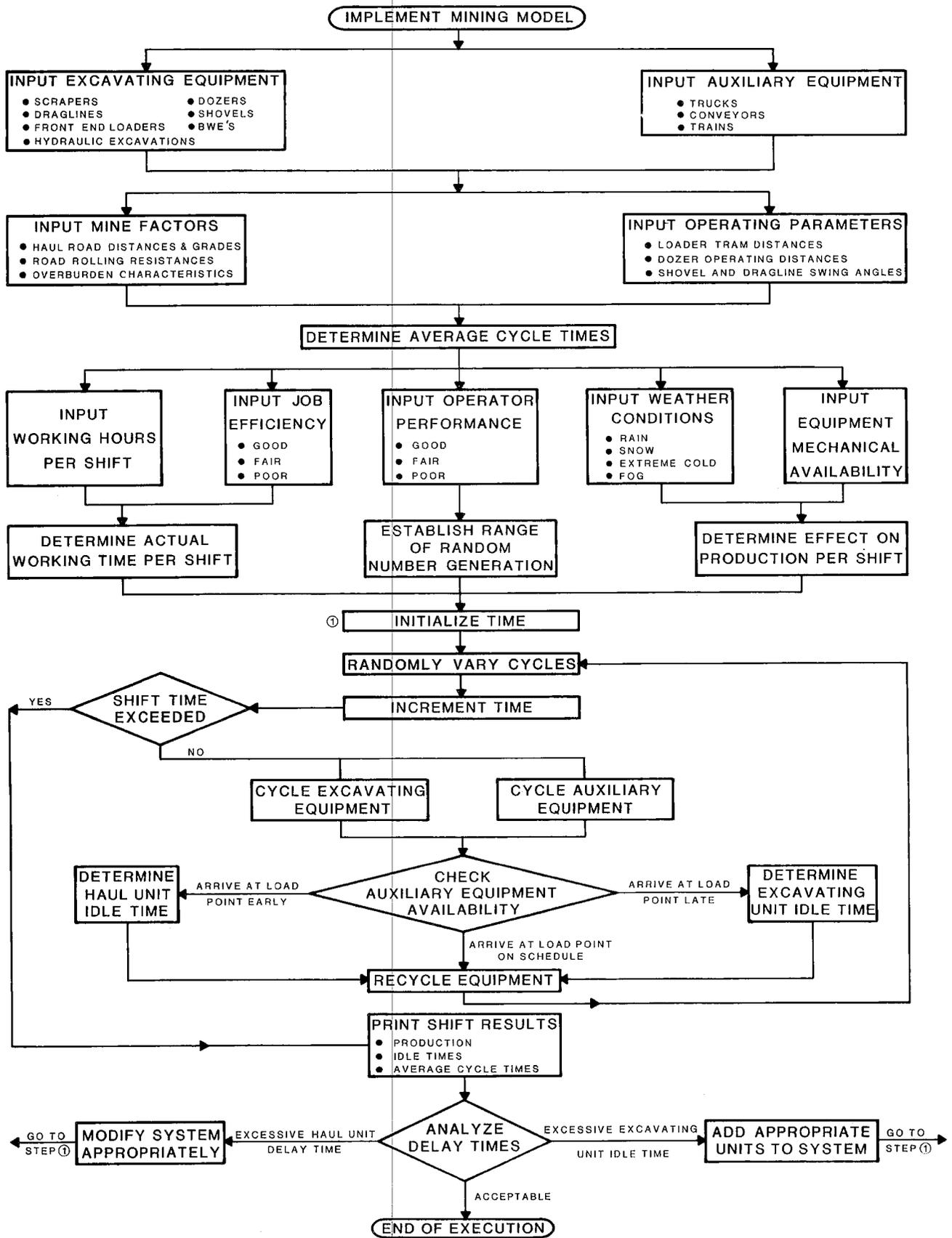
## **SYSTEMS ANALYSIS**

Assessing overburden production levels in a mining system is a complex task due to the interaction and interdependence of unit operations and mining equipment. To facilitate concept evaluation, a computer model was employed to determine various equipment scheme cycle times and production levels. Each operation associated with

excavation and transportation of materials is simulated as a closed-loop, total system. Job activities related to operations of shovels, bucket wheel excavators, front-end loaders, conveyors, trucks and trains are combined for multiple mining operations. The program is also capable of analyzing delay times, comparing them to specified limits and making changes in equipment numbers and sizes. Thus, in this manner, the optimum scheme employing specified types of equipment can be ascertained and evaluated. The resultant equipment selections reflect the best combinations to maximize the utility of individual units and attain desired production goals.

Figure 7 illustrates a general flowchart for the program. Working on a one (1) to five (5) second time increment basis, mining operations are simulated, compiled and cross checked before the next time increment is initiated. Total simulation time is determined by the amount of time in a shift or series of shifts during which the desired simulation takes place. After elapsed time is checked against total simulation time, each equipment sub-assembly is individually called. All equipment items within a particular sub-assembly are then simulated before elapsed time is once again incremented. Upon completion of one shift, delay time is analyzed with units showing excessive waiting time being modified in number or size. An entire shift is then resimulated in the same manner.

All data utilized for the systems analysis was obtained from manufacturer's specifications. Time slices representative of a typical full production year in the life of the concepts were chosen for the simulations. Haulage profiles, pit dimensions and other operational parameters were taken from plan maps and cross sections developed for each concept. Production rates per shift were then computer generated for each scenario. Engineers and technicians utilized this data to expand these shift rates into annual production levels. Delay times for such items as dragline relocations (deadheading), site preparation, road construction and new cut development were incorporated into these schedules to reflect "true to life" situations. Actual concept analyses are discussed individually in the following section.



MINE SIMULATOR FLOWCHART

FIGURE 7

## PITCHING SEAM CONCEPTS

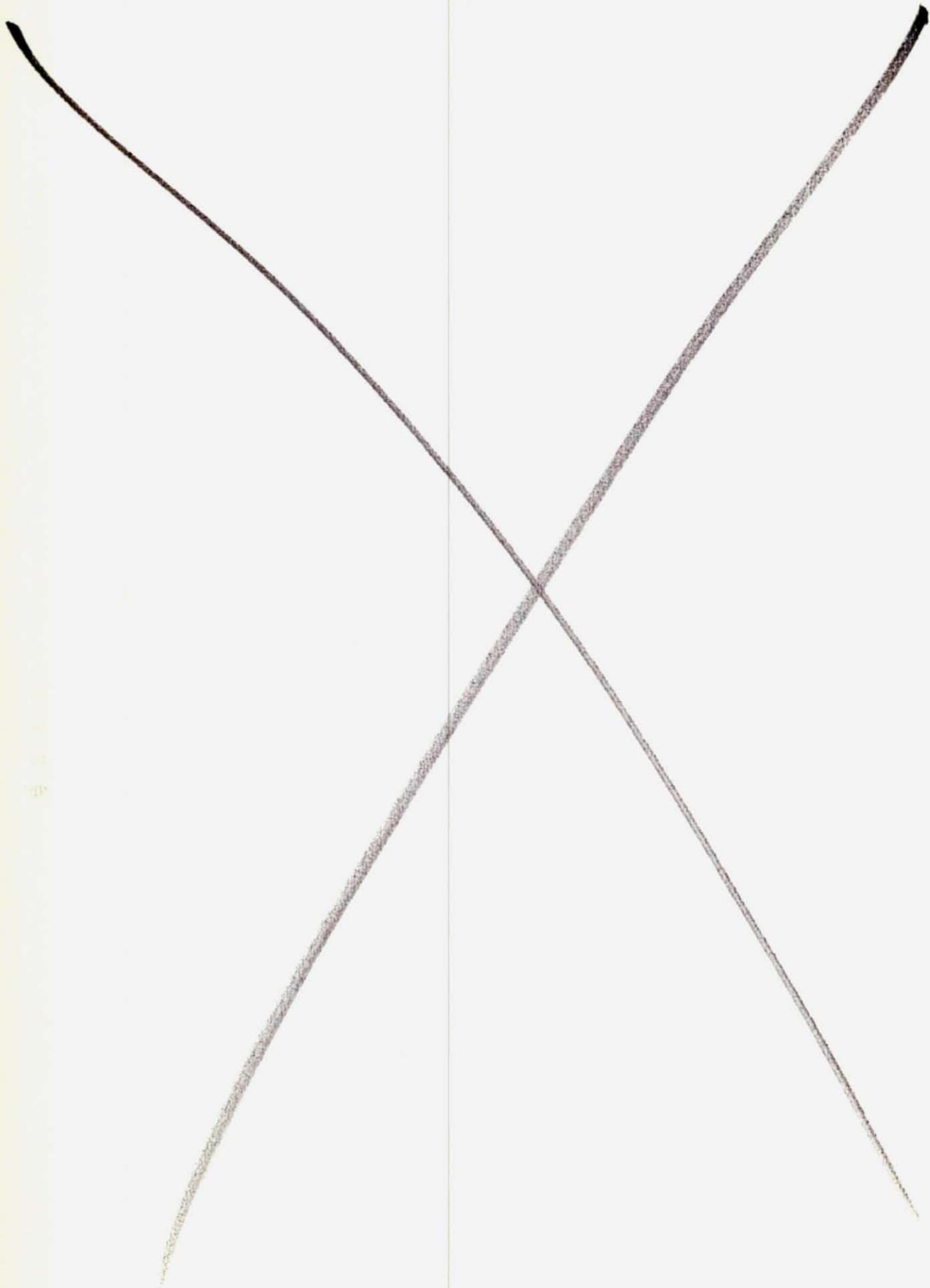
### GENERAL

Presenting mining concepts developed during this study, the following section contains narratives describing unit operations associated with each extraction scenario. Additionally, artist's drawings, plan maps and typical cross sections have been added to facilitate an understanding of each technique. Detailed cost analyses similar to those provided for the case history mines have also been generated.

One additional evaluation procedure was utilized to scrutinize these concepts — sensitivity analyses. Key economic parameters projected for each technique were varied from 0 to +60% of the original expected cost. Direct effects of this change on other economic parameters were calculated and the impact of this variance on projected coal selling prices was then plotted. This type of analysis brings to light the most critical economic parameters for a mining scheme and is invaluable in determining the advantages of one concept over another. Further, the range of 0 to 60% was selected to allow individual reviewers the capability of evaluating any concept with respect to his personal experience or opinion pertaining to cost variables.

It should be brought to light at this time that the economics generated for each scheme are representative of annual costs incurred during a year of full production and, accordingly, may not exhibit large developmental expenses. Additionally, the drawing and cross sections of each concept have been included to depict equipment layouts and pit configurations — they are not engineering drawings representing detailed design work which should be performed prior to concept implementation.

One additional note — because of the similarity of Concepts 1, 3, and 4 (Tandem Dragline Techniques), the economic and production projections were nearly identical. For this reason, there is a combined economic analysis for schemes 3 and 4. The primary difference between the remaining economics (1 and 3/4) is the use of conveyor rather than truck coal haulage.



## **STRIKELINE MINING/TANDEM DRAGLINES - CONCEPT 1**

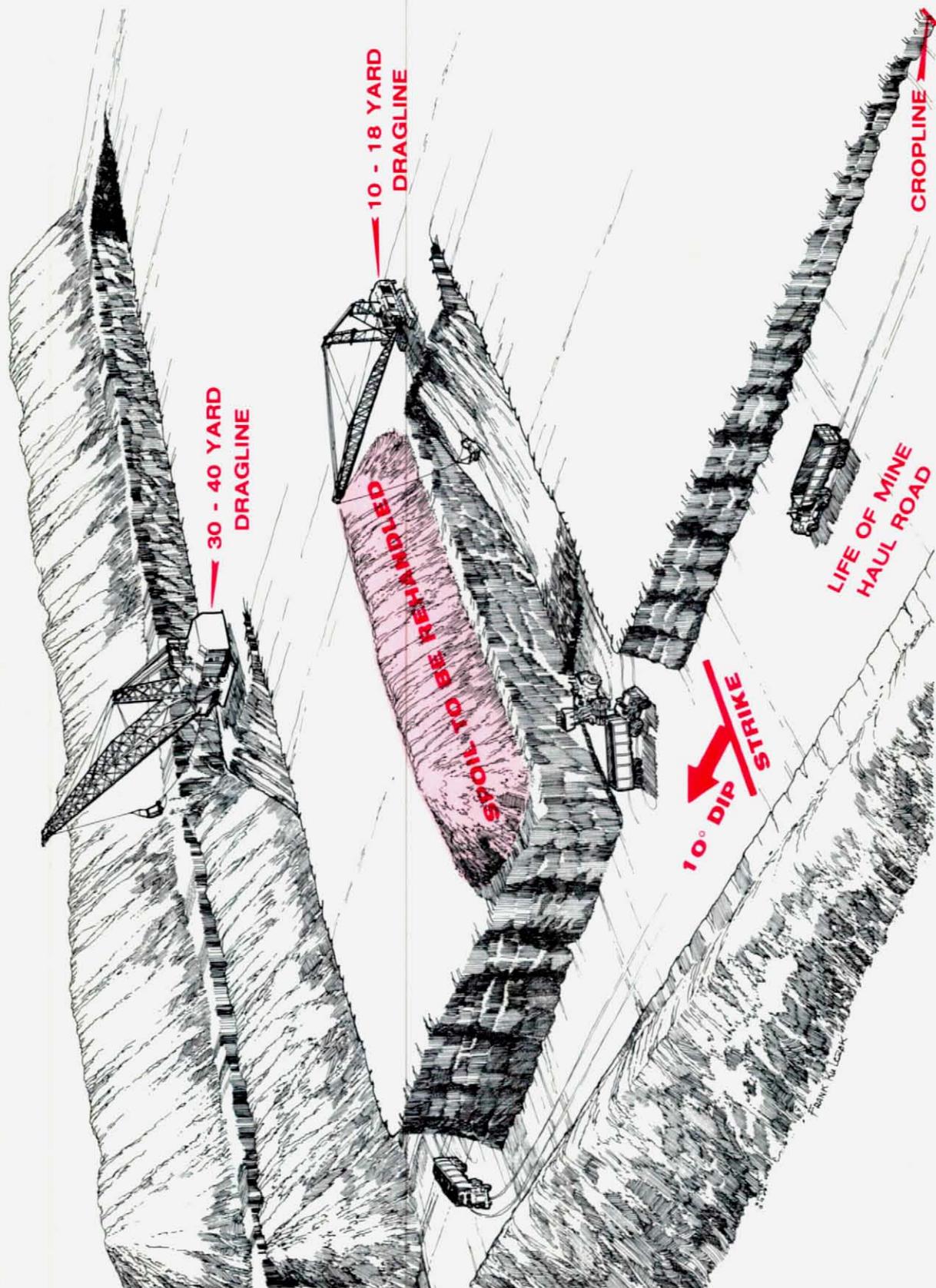
### **General**

This concept is designed as a strikeline mine utilizing two draglines operating in parallel pits perpendicular to an initial box cut made by the larger dragline. The mine will advance up the dip and complete one half of the property before starting operations on the adjacent area. A larger 36 cubic yard dragline will operate in the deeper cover and a smaller 12 cubic yard dragline will begin at its maximum economic digging depth. Coal loading will take place simultaneously in both active pits with a 7.5 cubic yard front-end loader as the primary loading equipment in each. The operation will require that each pit have a component of two or three 50 ton bottom rear trucks for maximum efficiency.

### **Site Development**

Several 500 horsepower bulldozers will clear and grub the smaller shrubs and trees after any larger or commercial grade timber has been removed by contracted logging. Topsoil will be removed, segregated, and stockpiled for eventual reclamation using 21 cubic yard scrapers. Topsoil will be stockpiled as near the active site as possible to minimize rehaul during reclamation. Crews and equipment used for site preparation as well as reclamation will be on an eight hour, one shift per day, 250 day per year schedule.

The initial box cut will be made as a sloping ramp directly down the dip of the coal ( $8^{\circ}$ ) to the maximum economic digging depth (150 feet) of the 36 cubic yard dragline. This initial cut will be developed as a life-of-mine main coal haul ramp from the two active dragline pits. Case History Mine 1 was employing this approach which minimizes haulroad construction costs and is especially effective for smaller reserve tracts. Other access roads will be constructed and maintained with bulldozers and graders. Since the terrain is level there should be little difficulty siting and maintaining these access roads throughout the duration of active mining.



## Overburden Handling

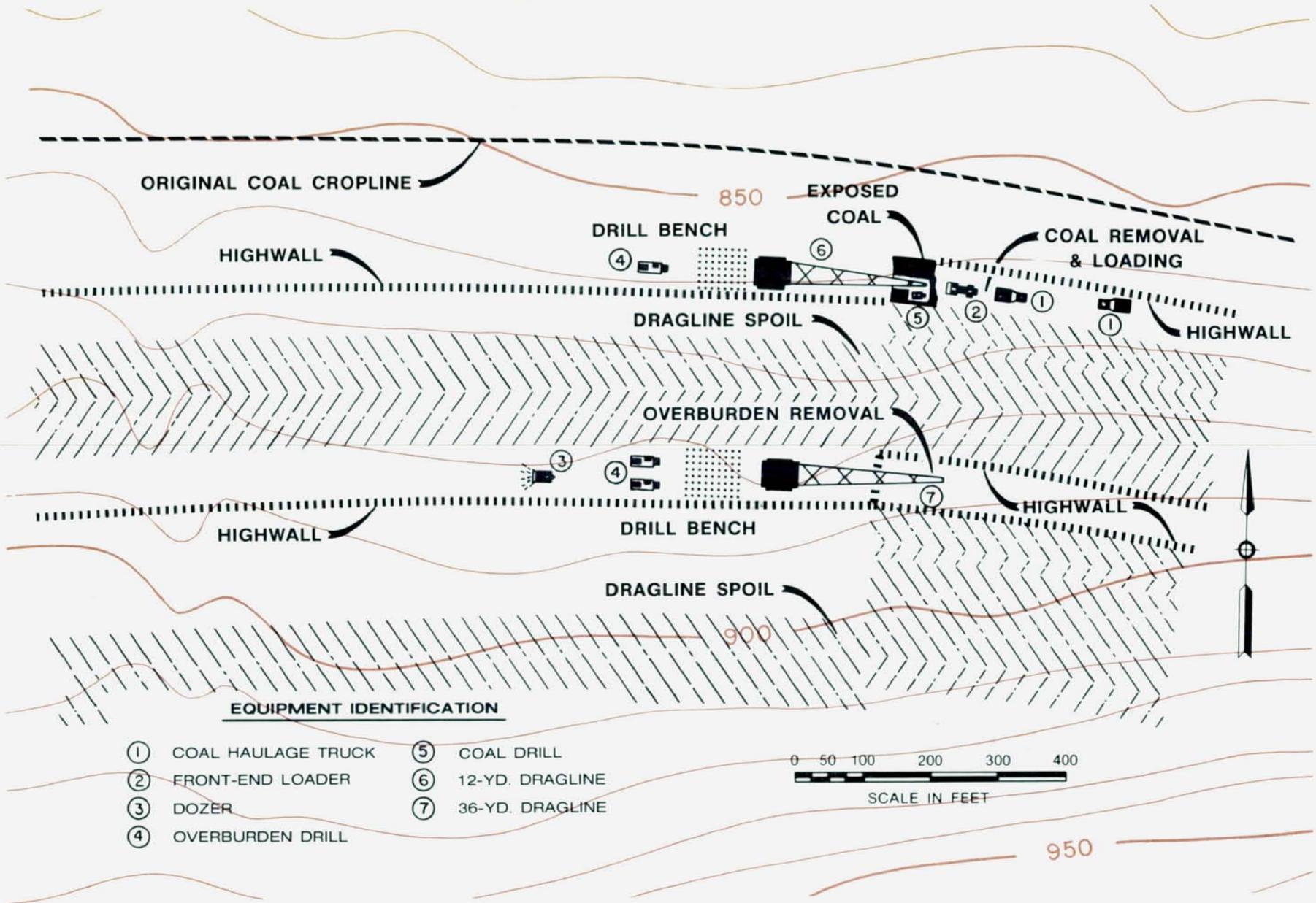
For the operation of this mining system, continual overburden removal in two pits will require the use of two overburden drills. On the 36 cubic yard dragline pit with the deeper coal, two 9 inch air rotary drills will be used. On the shallower overburden, one 9 inch air rotary drill should be used. The drilling pattern and ANFO powder factors to be used in blasting will be varied according to the hardness of the overburden. The level terrain may allow scrapers to prepare adequate drill benches as they remove topsoil.

A major constraint put upon this mining method is the necessity for loaded coal trucks to traverse the grade resulting from following the dip of the coal on this initial cut. This will restrict it to coal seams dipping 8 to 10° or less, unless conveyor haulage is used. As previously discussed, haulage on excessive grades reduces cycle times and adds to vehicle maintenance costs.

Two primary overburden removal units are planned for use at this mine. Figure 8 depicts a typical application of strikeline mining with dragline. A 36 cubic yard dragline will begin removing overburden from the deepest (150 feet) economically recoverable coal at the end of the initial box cut. It will progressively, by parallel cuts, move up the coal dip until it encounters the first cut of the smaller dragline which began overburden removal at its maximum digging depth (75 feet). The smaller dragline will progress up the dip of the coal until it reaches the coal outcrop. Both units must deadhead from completion of one cut to initiation of the subsequent parallel pit. However, this allows for removal of the last block of coal in each pit prior to backfilling. Figures 9 and 10 illustrate application of "Strikeline Mining/Tandem Draglines" in the setting defined for the representative mine site. The disposition of individual equipment units within the mine plan can be visualized through examination of Figure 9, while Figure 10 emphasizes the constraints imposed due to opposing surface and coal slopes. This effect of rapidly increasing cover limits the number of cuts feasible for each dragline.

- ◀ FIGURE 8 - Concept 1 - Artist's Sketch Depicting
- ◀ Strikeline Mining/Tandem Dragline Approach.

78 -  
67  
63



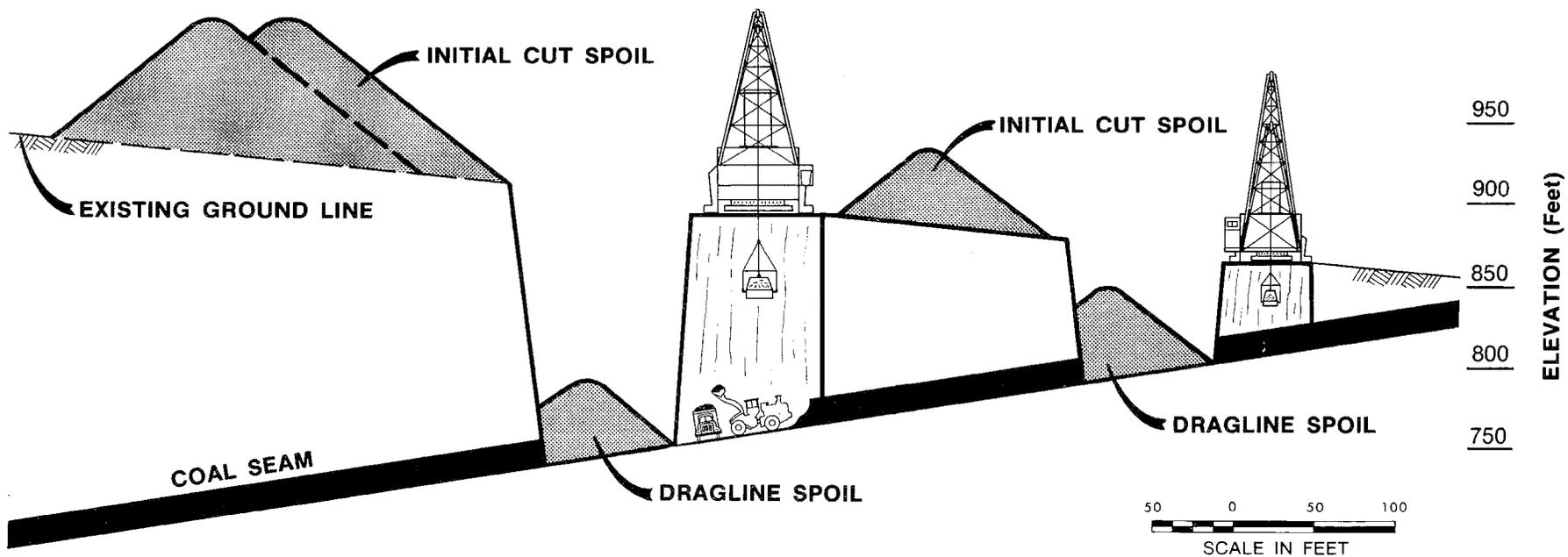
**EQUIPMENT IDENTIFICATION**

- |                      |                   |
|----------------------|-------------------|
| ① COAL HAULAGE TRUCK | ⑤ COAL DRILL      |
| ② FRONT-END LOADER   | ⑥ 12-YD. DRAGLINE |
| ③ DOZER              | ⑦ 36-YD. DRAGLINE |
| ④ OVERBURDEN DRILL   |                   |

**CONCEPT 1 - STRIKELINE MINING/TANDEM DRAGLINES  
MINE LAYOUT PLAN**

FIGURE 9

- 79 -



**CONCEPT 1 - TYPICAL CROSS SECTION  
OF MINING OPERATIONS**

**FIGURE 10**

Rehandle of spoil will occur when the larger dragline reaches its final cut. At this point it will be forced to remove and stack the spoil from the first cut of the smaller dragline. Since the amount of spoil from the first 12 cubic yard pit will be fairly small, this does not represent a serious constraint (10% of total volume). Spoil from the first cut of the 36 cubic yard dragline may have to be hauled to help fill the final 12 cubic yard cut, but much of it will be distributed in the area mined out by the larger dragline and central key cut. Overburden removal operations are scheduled for three 7¼ hour shifts per day, 300 days per year.

### **Coal Loading and Transport**

The coal will be shot using ANFO. The system proposed is to use one 7.5 cubic yard front-end loader for loading into a fleet of five 50 ton bottom dump trucks in the two active areas. This front-end loader/truck system will ensure mobility and flexibility for loading and haulage. Coal loading is scheduled one shift per day, 250 days per year.

### **Reclamation**

Reclamation will be concurrent where possible. 500 horsepower bulldozers will be used to top the spoil piles and 21 cubic yard scrapers will be used for the final surface leveling to match the original terrain. Regrading by bulldozers and scrapers will be fairly simple since the final contour is to be level with the surrounding surface. Topsoil will be spread to near its original thickness using the scrapers to distribute it. The final cuts of both the 36 and 12 cubic yard draglines and the initial box cut/haul ramp may require the movement of spoil from the first 36 cubic yard dragline cut to the shallower end of the pit. The spoil swell factor may overcome the final cut haulage requirements, but the initial box cut will require a continuous loop scraper spoil haulage system with bulldozers for regrading and leveling.

## General Concept Analysis

An up-dip mining system affords several advantages. In this case spoil stability problems should be almost eliminated. The larger dragline may have problems on its final cut because of the adjacent mined area, however, they should be minimal. Spoil from the smaller dragline will be capped by dozers to provide a bench for the 36 yard dragline which can easily cast this material as well as the final cut overburden.

Using this approach, both draglines will start digging at the economic limit and work toward shallower cover. They will be operating under optimum open cut conditions and productivity should be optimized. Loading coal from both pits simultaneously will give high production and keep up with the draglines' fairly high rate of advance.

As the artist's drawing and typical cross section show, this concept entails considerable spoil rehandle. All overburden removed from the key cut and both draglines' initial strikeline cuts will require rehandle. The material placed outside the mine area will need to be adequately stabilized until it is used to fill the central haul ramp and final cropline cuts after mining is completed. To accomplish this, a small work force and equipment fleet will operate after coal removal is finalized. All of these factors will add to the overall mining costs that can be anticipated. The effect of this on the representative mine site is an additional \$0.25 per ton of coal mined. However, reserve areas with less severe slope differentials will show significantly less economic impact.

Should spoil stability problems develop, especially if steeper dips are mined, as the larger dragline makes its final cut it may become necessary to leave a coal "fender". By establishing the barrier, the small draglines first cut spoil on the up-dip side should be stabilized allowing at least partial recovery of the coal in the final cut.

Following is a summary of important economic and production statistics generated for the Strikeline Mining/Tandem Dragline Concept.

These statistics reflect detailed evaluations included in the Appendices and are specific to conditions encountered through projected development of the representative mine site.

**TABLE 6**  
**CONCEPT 1 - ECONOMIC PARAMETERS**

ANNUAL OPERATING COSTS	
Manpower	\$ 3,677,000
Operating Supplies	4,705,000
Auxiliary Cost	6,639,000
Indirect Cost	1,257,000
Fixed Cost	524,000
Depreciation	2,959,000
<b>TOTAL ANNUAL OPERATING COST</b>	<b>\$19,761,000</b>
<b>ANNUAL COAL PRODUCTION</b>	<b>1,820,000 Tons</b>
<b>OPERATING COST PER TON</b>	<b>\$10.86</b>
<b>DISCOUNTED PRICE PER TON (15%)</b>	<b>\$13.28</b>

## **DIAGONAL MINING/DOZER EXCAVATION - CONCEPT 2**

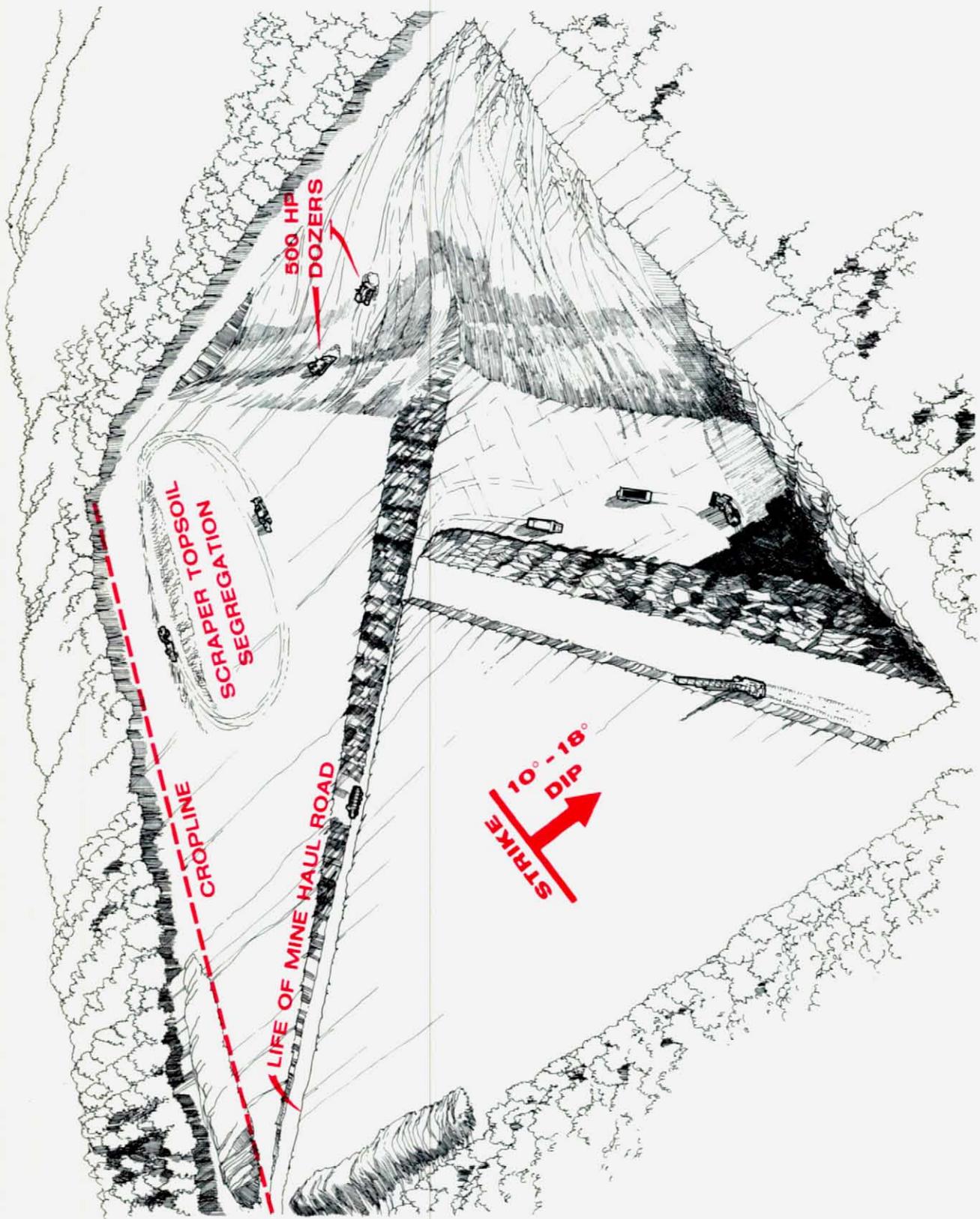
### **General**

This concept presents a diagonal mining system for use where steeper dips and confined areas create difficult mining conditions. Two central design factors are the diagonal key cut, expanded at the lower end to form a spoil containment area, and the use of heavy dozers (500 horsepower or larger) as primary stripping units. Initial development work will be accomplished with a 12 cubic yard front-end loader and five 50 ton end dump rock haulers. During the development phase, these units will double as coal loading/haulage equipment. Development overburden haulage is necessary to remove material and create spoilage area for subsequent dozer excavation. When the mine reaches full production, with the dozers moving all overburden, the front-end loader/truck team will be phased into full time coal production. However, if additional reserve blocks must be developed for future mining, these trucks could be assigned to this work, allowing more effective use of coal haulage trucks.

By excavating the key cut on a diagonal to the true dip, the final grade of the haulage route is reduced to approximately half of the dip. With an upper grade limit of 10° for most conventional haulage trucks, this would allow mining of seams dipping up to 20°. Design and excavation of the key cut and spoil containment area will control the entire operation. Sufficient storage volume must be created to provide ample room for the dozer push to operate efficiently and to prevent the operation from becoming spoil bound as the mine advances. Another controlling factor to the application of this system will be the availability of an adjacent area capable of containing the excavated key cut material in an engineered fill.

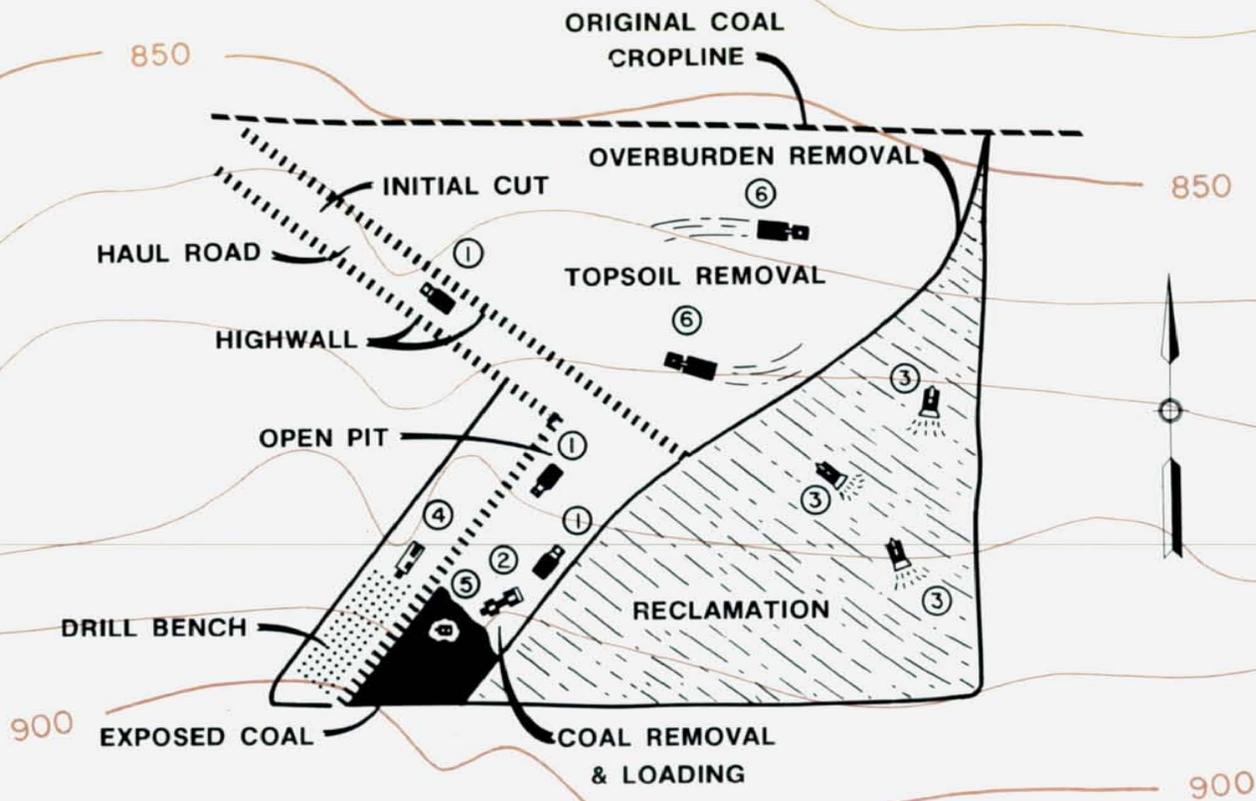
### **Site Development**

Clearing and grubbing operations will be conducted as existing vegetative cover dictates. In this scenario, all marketable timber will be



harvested, with the remaining trees felled and windrowed. Dozers will initiate clearing and grubbing on the area to be excavated. All available topsoil on the key cut and spoil containment areas will be removed, prior to excavation, with 21 cubic yard self loading scrapers and stored at the cropline for redistribution when mining is completed. Once the key cut area is cleared, one dozer will assist the excavating units, and the others will continue to clear the remaining area. As the mine reaches full development, both scrapers will remove topsoil in advance of the drilling operations and immediately redistribute it over the regraded areas. By utilizing this technique, reclamation efforts will closely follow the mine's advance and not extend significantly beyond the operating life of the mine.

As pointed out earlier, the development of the key cut/haulway and spoil containment area will be critical factors in this operation. The volume of material to be excavated will depend upon the swell factor associated with the overburden, the thickness of the coal seam to be extracted, and the degree of compaction (generally less than 10%) that can be expected. With an assumed swell factor of 30%, less than 30% of the in-place overburden will be removed to prevent the advancing operations from becoming spoil bound. Development work will be accomplished with a 12 cubic yard front-end loader excavating the shot material. One of the dozers will be assigned to assist the loader and drill crew. Rock haulers will transport the excavated spoil to the fill site. Coal removal during the development phase will be carried out by the front-end loader/truck team as conditions dictate. Because the central key cut will be used as a life of the mine haul road, a level bench will be established in the pit floor as the development work advances. If this were not done, operating and maintenance problems could develop as the coal trucks repeatedly negotiated the slightly sloping haul ramp. As the mine reaches full development and the dozers take over the overburden removal operations, the front-end loader/truck team will be phased into full scale coal removal.



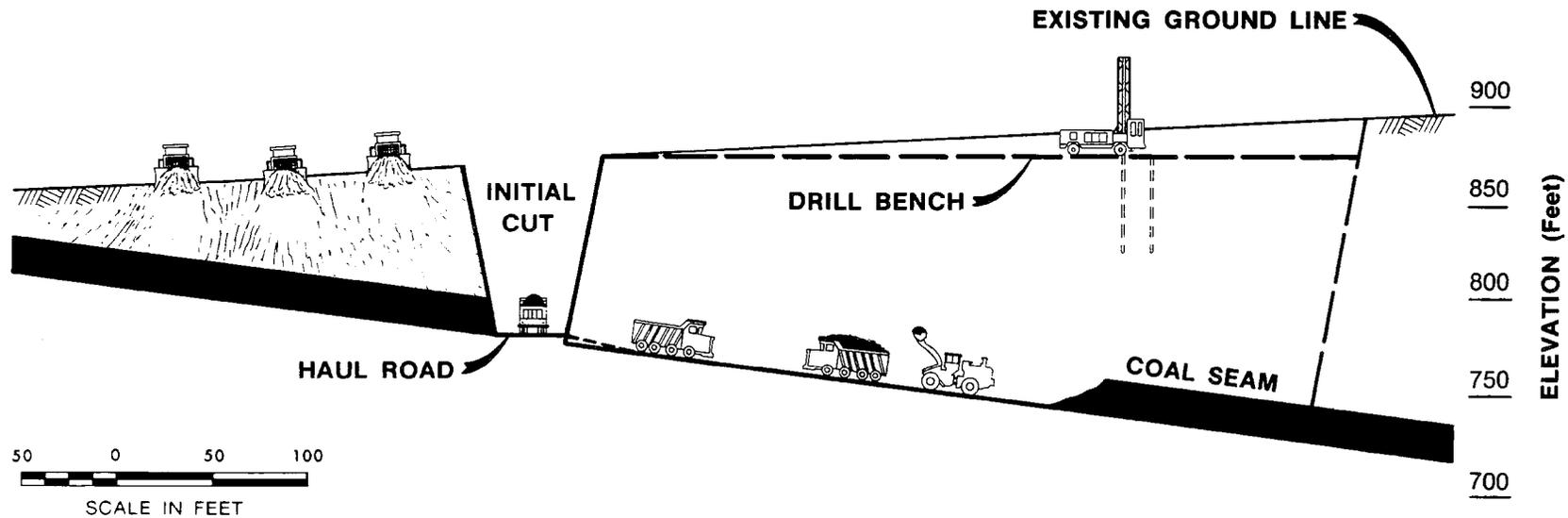
**EQUIPMENT IDENTIFICATION**

- |                      |                    |
|----------------------|--------------------|
| ① COAL HAULAGE TRUCK | ④ OVERBURDEN DRILL |
| ② FRONT-END LOADER   | ⑤ COAL DRILL       |
| ③ DOZER              | ⑥ SCRAPER          |



**CONCEPT 2 - DIAGONAL MINING/DOZER EXCAVATION  
MINE LAYOUT PLAN**

FIGURE 12



**CONCEPT 2 - TYPICAL CROSS SECTION  
OF MINING OPERATIONS**

**FIGURE 13**

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## Overburden Handling

Blasthole drilling will be done using 9 inch air rotary drills. ANFO will be the principal blasting agent with powder factors governed by site specific overburden and coal characteristics. Property size and rate of mine advance should not necessitate more elaborate drilling techniques. A truck mounted drill rig should prove more flexible than a tracked unit when full production is reached, and drilling is conducted on alternating sides of the central haulage ramp. Tentative operating criteria will have all personnel working three shifts a day, six days a week with standard UMWA vacation and holiday schedules. Site specific overburden characteristics or production requirements could necessitate other operational modifications.

Once the key cut and spoil containment area - a triangular open pit excavated in the deepest cover at the corner of the block being mined - have been excavated, the dozers will begin their overburden removal operations. As Figures 12 and 13 illustrate, shot material will be moved by the dozers pushing into the spoil containment area. This operation will have a blasting system designed to provide optimum across pit spoil displacement with minimum ground shock and air blast. Over the distances and grades (300 ft and 10%) involved, these high horsepower dozers can outproduce most or all other excavating equipment. Additionally, other overburden handling systems would require at least two D-9 size dozers as support equipment for clearing and grubbing, drill benching, and pushing shot material to loading equipment. By using large dozers for these functions as well as for primary stripping, the overall equipment fleet is reduced, and the dozers are efficiently utilized. One other point is that as the dozers move the overburden, it is placed directly into the worked out pit to a level approaching approximate original contour. Good spoil compaction should be achieved by the dozers' tramming. As the pit is refilled, the only additional reclamation efforts required will be redistribution of the topsoil and revegetation. If the initial excavation is adequately designed, the spoil rehandle required to fill the

final cut will be minimized and accomplished with a few days of dozer work.

### **Coal Loading**

Drilling will be done using a 3 inch coal drill and shot using ANFO. As mentioned earlier, the front-end loader/truck team will be phased into coal production as operations reach full-scale. Because coal loading will alternate from one side of the central haulage way to the other, for half of the time coal haulage from the working face will be against a fairly steep grade. This haul should be accomplished on a rough diagonal between the strike and the dip and so would not be substantially steeper than the haul road. coal production will have to be closely matched with overburden removal to prevent idle time by either crew or coal production delays as a result of lagging overburden removal.

### **Reclamation**

At full production, this mining system should provide ideal concurrent reclamation. As the spoil is pushed by the dozers, final surface grade will be established, and the material will be compacted to reduce post mining settling and enhance overall stability. The two scrapers should be able to coordinate topsoil removal and redistribution over the regraded areas with the mine advance. When the mine reaches the cropline, either the dozers or the scrapers can be used to redistribute the final cut spoil into the pit and replace the stockpiled topsoil.

A large number of revegetation options would be feasible on this type of reclaimed area. Return to original premining conditions is a viable alternative, however, the area would be well suited to an intensive forestry program such as tree farming for pulpwood or Christmas tree production. Another alternative, with interesting possibilities, is farming. The cleared, leveled land surface would lend itself well to various agricultural activities, and access would be established.

## General Concept Analysis

Where conditions are suitable, this will be a very effective, efficient mining system. The use of bulldozers as primary stripping units requires much lower capital expenditures than an equivalent dragline or haulback system without sacrificing productivity. Nearly all of the spoil material is contained within the pit, so offsite impacts are minimized. As each successive overburden lift is pushed into the containment area, it is compacted by the dozers. By placing spoil against the highwall on the down-dip side of the pit, no spoil stability problems should be encountered.

Reclamation, to approximate original contour, will be concurrent with the mine's advance. Detailed premining engineering and geologic studies will allow design of the excavated area to handle the remaining in-place spoil plus swell. By doing this, total reclamation of the mined area to original contour will be facilitated.

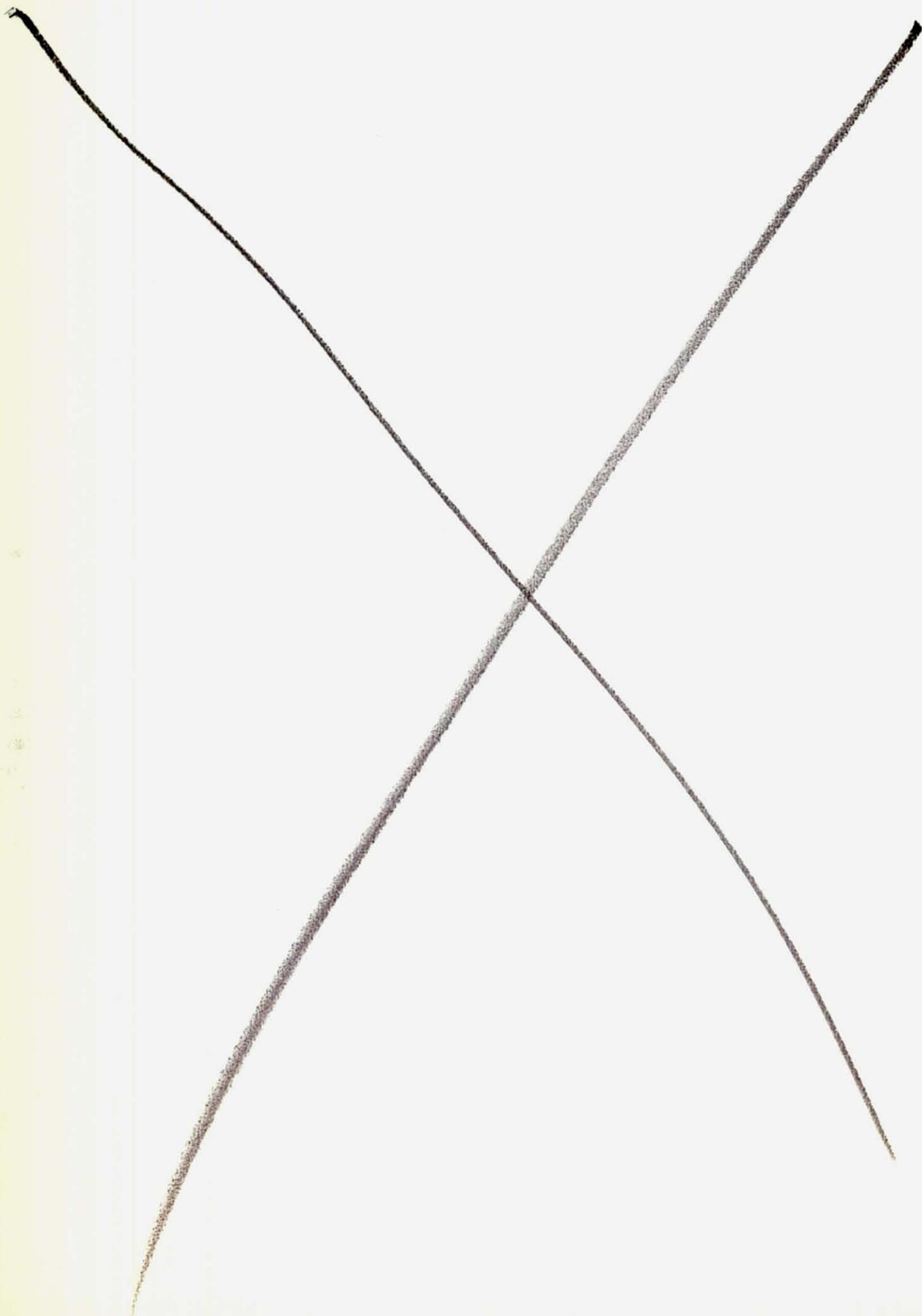
As with any mining system, there are certain problem areas that can be anticipated with application of this concept. Any time spoil must be hauled offsite for disposal, problems can be expected. The major problems associated with fill construction have been overcome by years of practical experience. Good design and construction criteria will ensure a safe, stable disposal area.

At the stage of mine development shown in the illustration, water accumulation at the coal loading face could be a problem. The haul ramp will tend to concentrate any significant stormflows into the lower corner. Periodic pumping, as conditions dictate, will alleviate all but the most unusual water accumulations. Once the mine has advanced beyond the halfway point, the significance of potential water accumulations at the working face will be greatly reduced as the majority of surface runoff will be directed into the spoil area.

Establishing the diagonal haul ramp will reduce the impact of seam dip on coal haulage, however, up grade haulage will influence truck efficiencies. During premining engineering and geologic studies, particular attention must be given to evaluating the potential stability of the exposed strata along the central haul ramp. Stability of the up slope haul road highwall will be critical because it will be exposed for a prolonged period of time. This highwall is designated on the Mine Layout Plan (Figure 12) and consists of the northern face of the initial cut and permanent haul road. Table 7 provides a summary of key statistics relating to Diagonal Mining/Dozer excavation. The number reflects projection of the mining approach for a 20 year mine life in conditions common to the representative mine site. As previously mentioned, detailed information is provided in the Appendices.

**TABLE 7**  
**CONCEPT 2 - ECONOMIC PARAMETERS**

<b>ANNUAL OPERATING COSTS</b>	
Manpower	\$ 3,611,000
Operating Supplies	3,150,000
Auxiliary Cost	6,784,000
Indirect Cost	1,014,000
Fixed Cost	321,000
Depreciation	2,267,000
<b>TOTAL ANNUAL OPERATING COST</b>	<b>\$17,147,000</b>
<b>ANNUAL COAL PRODUCTION</b>	<b>1,900,000 Tons</b>
<b>OPERATING COST PER TON</b>	<b>\$9.02</b>
<b>DISCOUNTED PRICE PER TON (15%)</b>	<b>\$10.62</b>



## **DIPLINE MINING/TANDEM DRAGLINES - CONCEPT 3**

### **General**

This is a dipline mining system utilizing draglines operating two pits perpendicular to a central strikeline box cut. One 36-40 cubic yard dragline will operate down-dip from the box cut. A 12-21 cubic yard dragline will mine opposite it up the coal dip. Coal loading will be accomplished using a 7.5 cubic yard front-end loader with coal transport from the pit via conveyor haulage. As designed, twelve (12) mobile conveyor units - each 100' in length - will be advanced or retreated to facilitate removal of coal exposed by the draglines. Once the coal is removed from the pit area, standard haulage trucks can be employed to transport coal to the tipple or preparation plant.

### **Site Development**

Site development consists of vegetation removal, grubbing, if necessary, and the removal, segregation and storage of topsoil. These operations are expected to be continuous, functioning three shifts per day six days per week. Bulldozers in the 500 horsepower class will be used for primary vegetation removal and grubbing. Twenty-one cubic yard self loading scrapers will be used for topsoil removal, stockpiling, and eventual replacement during reclamation. The initial box cut will be made along the strike of the coal at the maximum operating depth of the smaller dragline. A dragline cut will also be established from the coal outcrop down dip connecting with the strikeline box cut. This access cut will be re-established as needed to accommodate the 1200' haulage limitation presented by the conveyor chain.

Spoil from the box cut will be placed alternately on the up-dip and down-dip side. This distributes the spoil to be rehandled evenly between



**FUTURE DEVELOPMENTAL CUT**

**CROPLINE**

**10 - 18 YARD  
DRAGLINE**

**STRIKE  
DIP**

**30 - 40 YARD  
DRAGLINE**

**LIFE OF MINE  
HAUL ROAD**

Frank M. Kuzubok

the two draglines and eliminates the possibility of the machine stacking beyond its ability. The initial box cut and subsequent cuts will become the main haul ramp out of the two active pits.

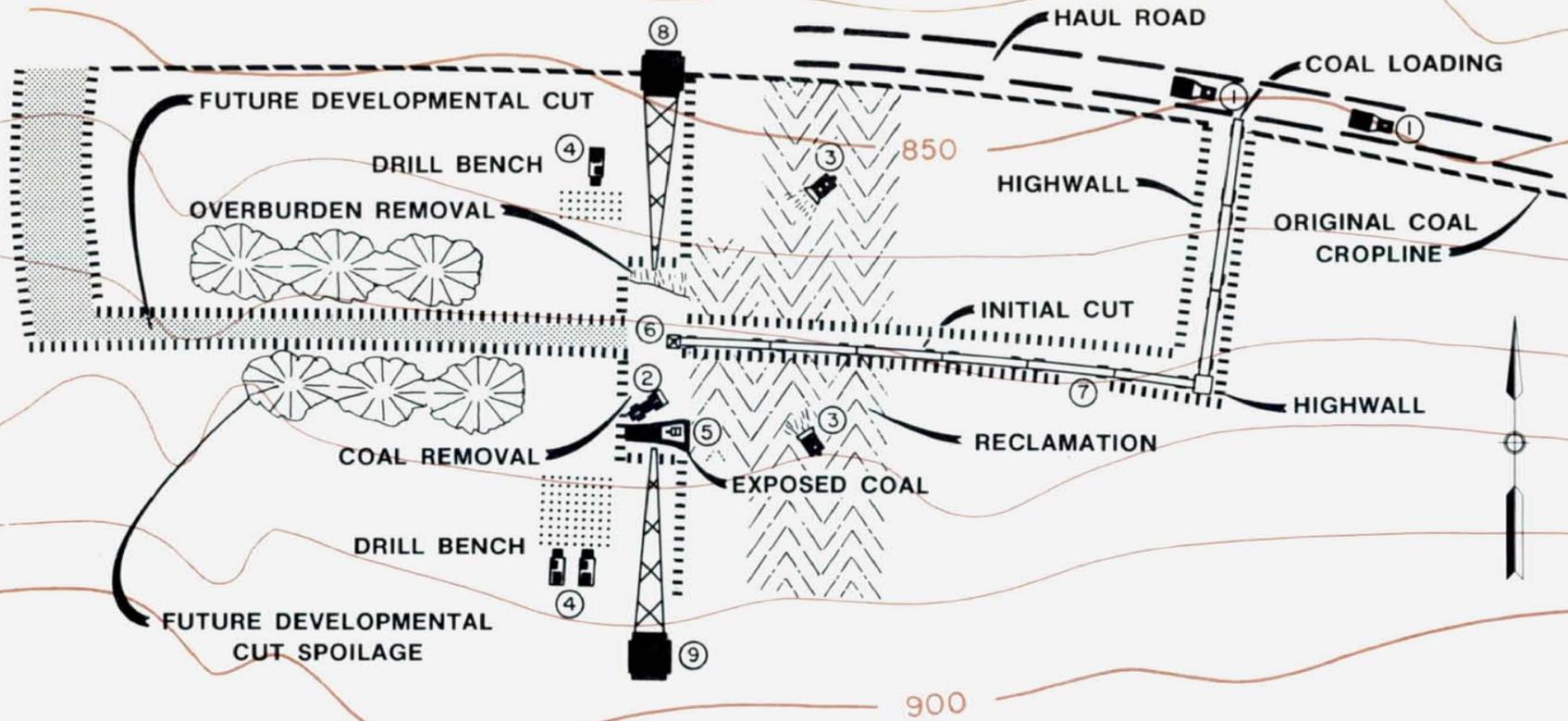
### **Overburden Handling**

Overburden removal will immediately follow site preparation with activities scheduled on the same three shift basis. Bulldozers will be utilized for dragline and drill benching in each pit. Two 9 inch air rotary drills will be used for the larger dragline, working in deep cover, and one air rotary drill for the smaller dragline, on the shallower overburden. ANFO will be the explosive used for all shooting. The drilling pattern and ANFO powder factors will be determined by the characteristic hardness and joint pattern of the overburden encountered. Vertical blast holes will be utilized.

A 36 cubic yard dragline will begin a pit on the down-dip side of the initial box cut and work the progressively deeper coal to its maximum economic digging depth. This requires deadheading back after each pit is completed but this will be a minimum distance. A smaller dragline will begin a pit on the up-dip side of the initial box cut opposite the larger dragline pit and mine up-dip to the coal outcrop. It should be noted that the draglines were sized to attain overburden removal rates necessary to achieve desired coal production. In addition, each machine was evaluated to ensure sufficient boom length to meet digging depth and spoil casting reach requirements.

With the proposed scheme, each dragline will, in opening each new cut, rehandle only 50% of the spoil removed from the box cut at that location. Since the initial box cut is to be made by the 12 cubic yard dragline, it can be made while the larger dragline is under construction. An alternative to this dragline rehandle would be the use of a truck haulage system to excavate and removal all box cut material. In large reserve areas these units could work one or two shifts per day, facilitating economic justification for their purchase.

70  
- 100 -



**EQUIPMENT IDENTIFICATION**

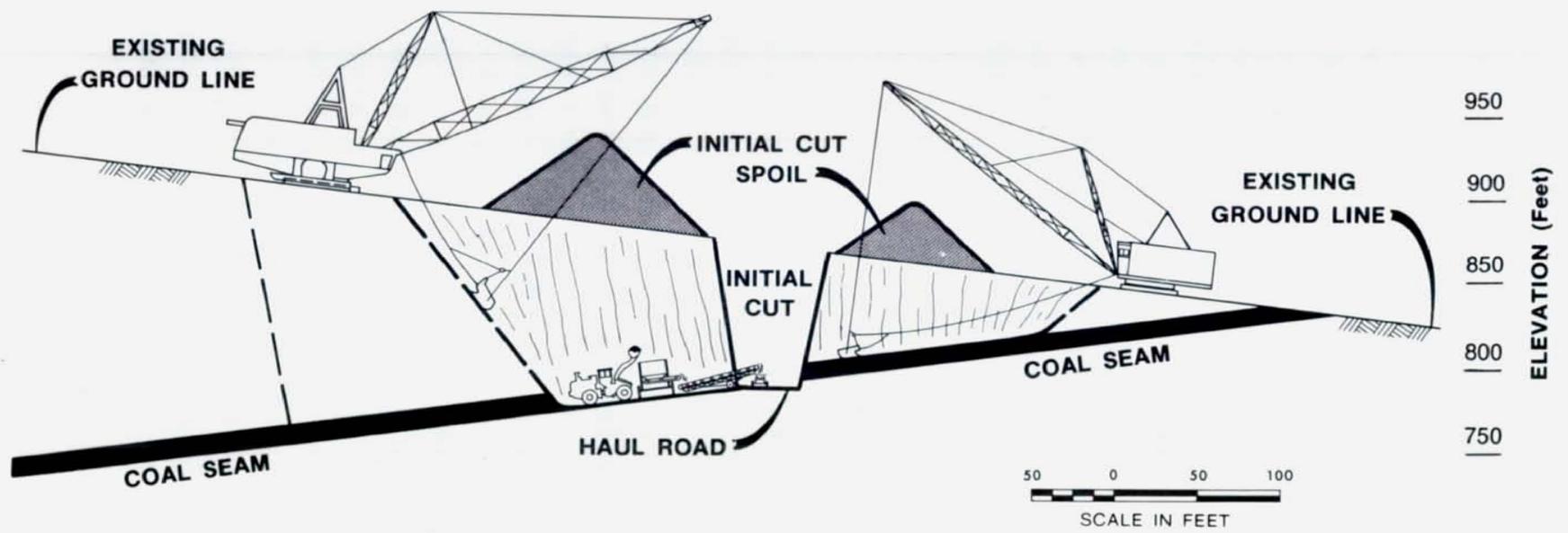
- |                      |                     |
|----------------------|---------------------|
| ① COAL HAULAGE TRUCK | ⑥ HOPPER FEEDER     |
| ② FRONT-END LOADER   | ⑦ PORTABLE CONVEYOR |
| ③ DOZER              | ⑧ 12-YD. DRAGLINE   |
| ④ OVERBURDEN DRILL   | ⑨ 36-YD. DRAGLINE   |
| ⑤ COAL DRILL         |                     |



**CONCEPT 3 - DIPLINE MINING/TANDEM DRAGLINES  
MINE LAYOUT PLAN**

FIGURE 15

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- 101 -



**CONCEPT 3 - TYPICAL CROSS SECTION  
OF MINING OPERATIONS**

FIGURE 16

## **Coal Loading and Transport**

Coal will be loaded from each pit alternately, necessitating flexible, mobile coal loading equipment to minimize travel time between the sites of active coal loading. A 7.5 cubic yard front-end loader system has been chosen. This loading equipment is standard throughout the industry and provides the necessary capacity to supply the mobile conveyor haulage system. A 3 inch coal drill and ANFO will be used to shoot the coal. Since coal loading will be alternating, with only one pit active at a given time, only one coal drill and shooting crew is required for all the coal. A single bulk explosives truck will be able to handle the requirements of loading blast holes for both overburden and coal shooting. Coal loading and haulage will be scheduled for one shift, five days per week.

## **Reclamation**

Reclamation will be concurrent with the advance of the two active pits. The same bulldozers which prepare dragline and overburden drill benches can be used to top off the spoil piles in preparation for final regrading. Since the land surface is fairly uniform originally, the final regrading will not require extensive contouring or terracing. It will be possible to push the spoil to near the original contour with bulldozers and complete the regrading with scrapers. Topsoil will be replaced to near its original depth. Revegetation will closely follow the advance of the mine. The final dragline cut and haul ramp will be filled after active coal removal has ceased. The spoil swell factor will have left enough excess material in the later stages of mining to fill the final cut, with bulldozers pushing material in the cut. Scrapers, working in a closed loop, will complete final cut regrading. The central haul ramp will also be filled in from excess material produced in earlier stages of excavation. Over the distances involved, the dozers and scrapers should be able to refill the ramp without extending reclamation efforts too far beyond the mine's operating life.

## General Concept Analysis

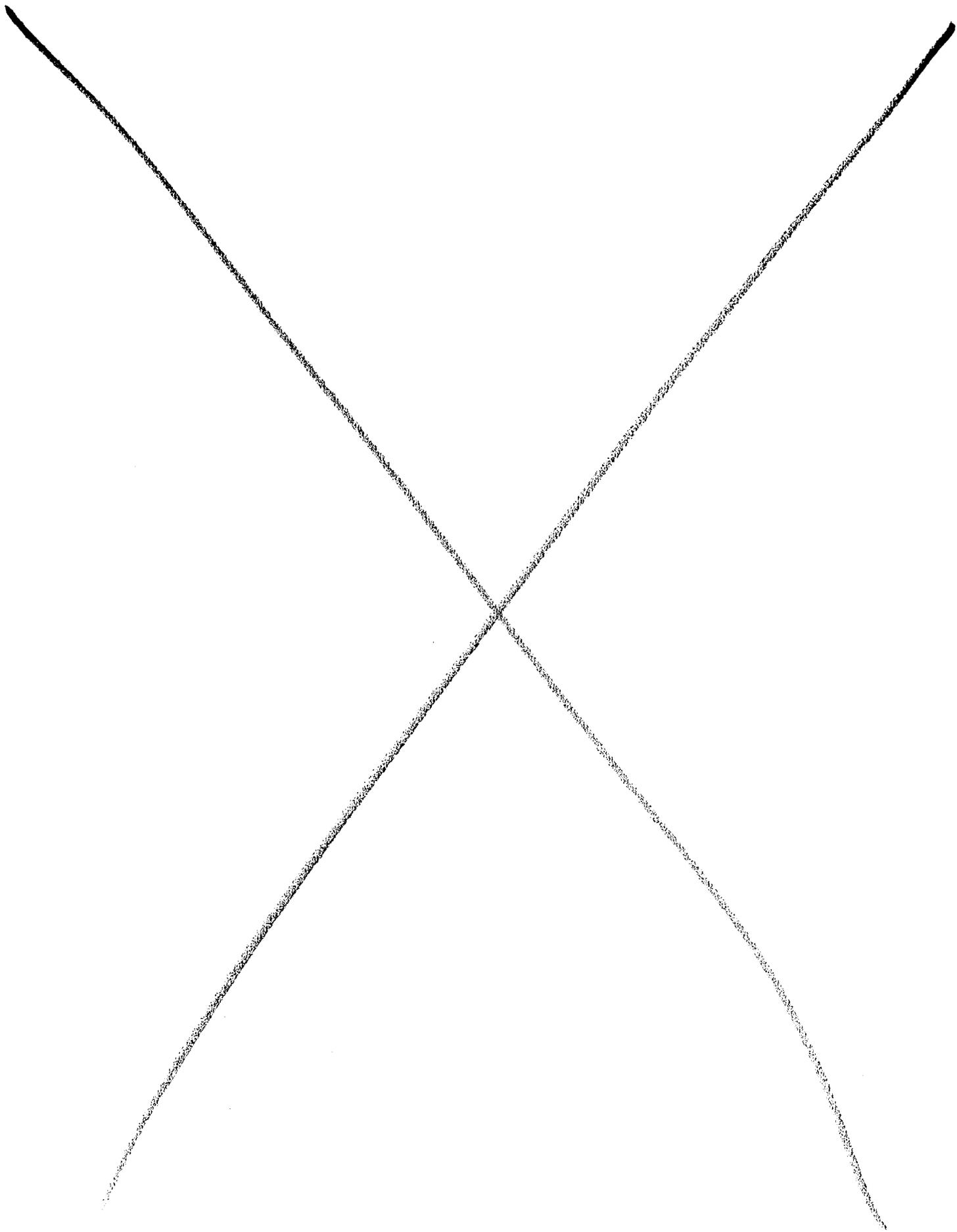
This system provides efficient, potentially economic recovery of coal seams with moderate dips. By using two draglines, one 36 cubic yard and one 12 cubic yard, both machines are operating in efficient open-cut range. Construction of the smaller machine will be scheduled to have it online while the larger dragline is under construction. This will allow mine development and coal recovery to offset some of the inherently high front-end costs.

Nearly all spoil will be contained in the pit. At the end of operations, or potentially as the mine advances, the first cut spoil will be used to refill the central haul ramp. This and normal swell of the overburden should facilitate reclamation of the site to, or very near, approximate original contour.

Coal loading and haulage from alternating pits will ensure a uniform rate of coal production. The flexibility of the front-end loader/conveyor team will allow increased coal recovery rates to meet unusual market considerations. A central haulway, along the strike of the coal, will be designed to have a level running surface to increase haulage efficiency and eliminate the problems of belt alignment on a slope surface.

Spoil rehandle will be the biggest problem facing this system. All overburden from the central key cut and the first dipline cuts will require rehandling. However, this material represents only a small percentage of the total in-place overburden. Additionally, by rehandling the spoil from the initial dipline cuts, backfilling of the haulway to approximate original contour should be achieved.

Dip of the coal will affect haulage from the lower pit. In areas where dips exceed 10° it is advantageous to use a conveyor assembly to transport the coal from the lower face to the central haul road. This would potentially allow mining of seams dipping to 18° and still allow use of trucks for the majority of hauling.



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## **DIAGONAL MINING DUAL DRAGLINE - CONCEPT 4**

### **General**

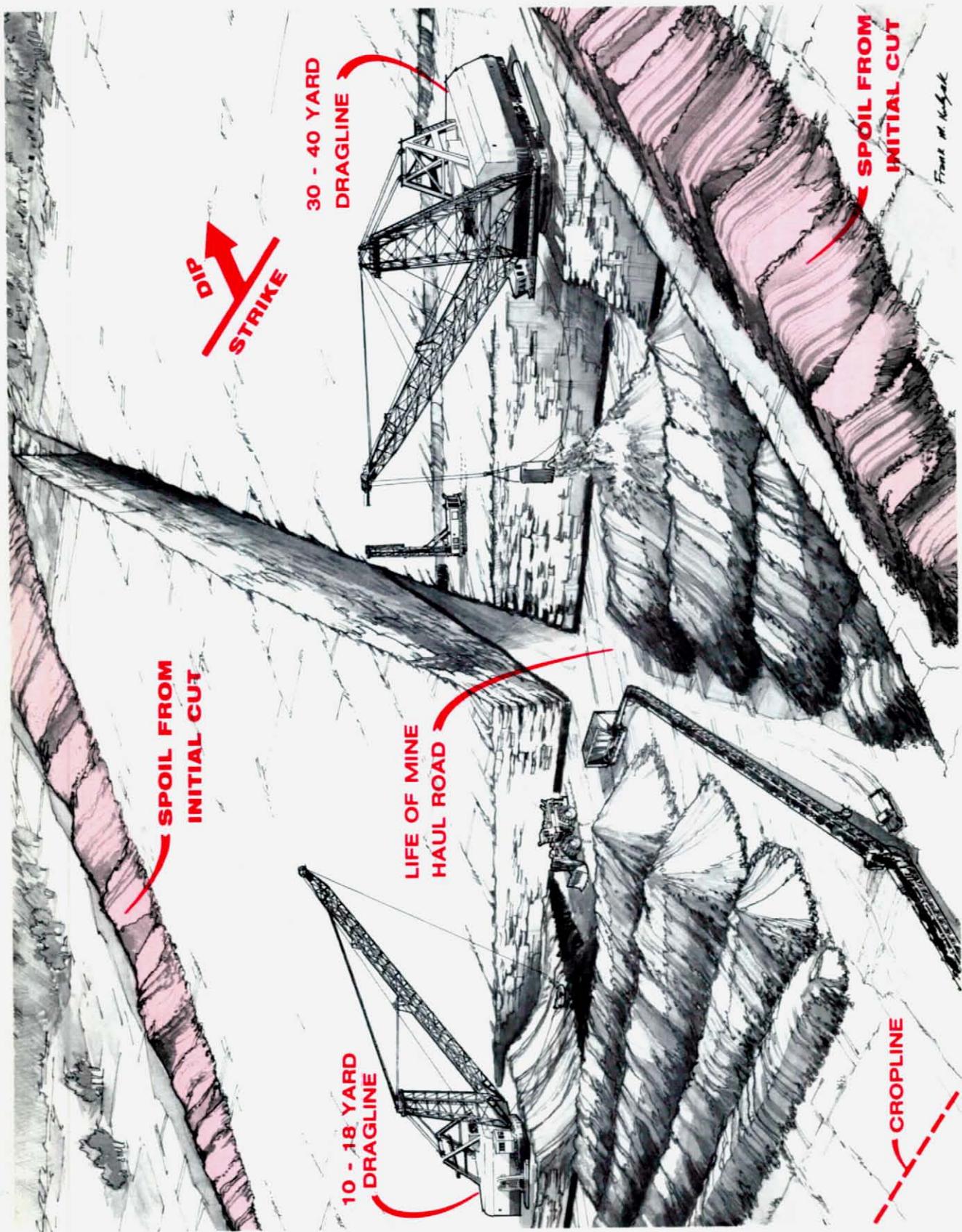
Concept 4, illustrated by Figure 17, presents a diagonal dragline mining system with potential for application in areas where coal dips exceed 10° and land ownership or reserve availability is in the form of distinct blocks. Original ground surface slopes could be less than or equal to the dip of the coal and not represent a significant operational constraint. A central diagonal key cut establishes a haul ramp for each reserve block and provides a free face for the draglines to initiate each cut. This mining scheme is much like Concept 2 with the main difference being that draglines can reach greater digging depths than dozers.

The advance of one dragline cut will be slightly staggered to facilitate coal removal as the draglines deadhead at the end of each pass. By alternating coal loading between pits, a uniform rate of coal production can be maintained, and the influence of changes in overburden removal rates should be minimized.

Because this is basically an area mine, clearing and grubbing operations will precede the pit's advance. However, the slopes involved will necessitate keeping these operations as close to the dragline bench as practicable to prevent erosion. Nearly all spoil will be contained in the pit. Reclamation, except for the central haul ramp, will be coordinated with the mine's advance.

### **Site Preparation**

The extent of site clearing and grubbing required will be controlled by site specific premining conditions. A brush and grass vegetative cover is assumed, with clearing and grubbing carried out by bulldozers. Scrapers will remove, stockpile and redistribute topsoil. Initial dozer and scraper activity will be focused on the central key cut area. Topsoil, from there, will be stored and stabilized for redistribution over the final cut and



haulway. Closely following, drilling and shooting of the haulage cut will begin. When the key cut area has been cleared and grubbed and topsoil removed these operations will begin at the cropline and advance with mining on a 3 shift, 6 day basis for 50 weeks per year.

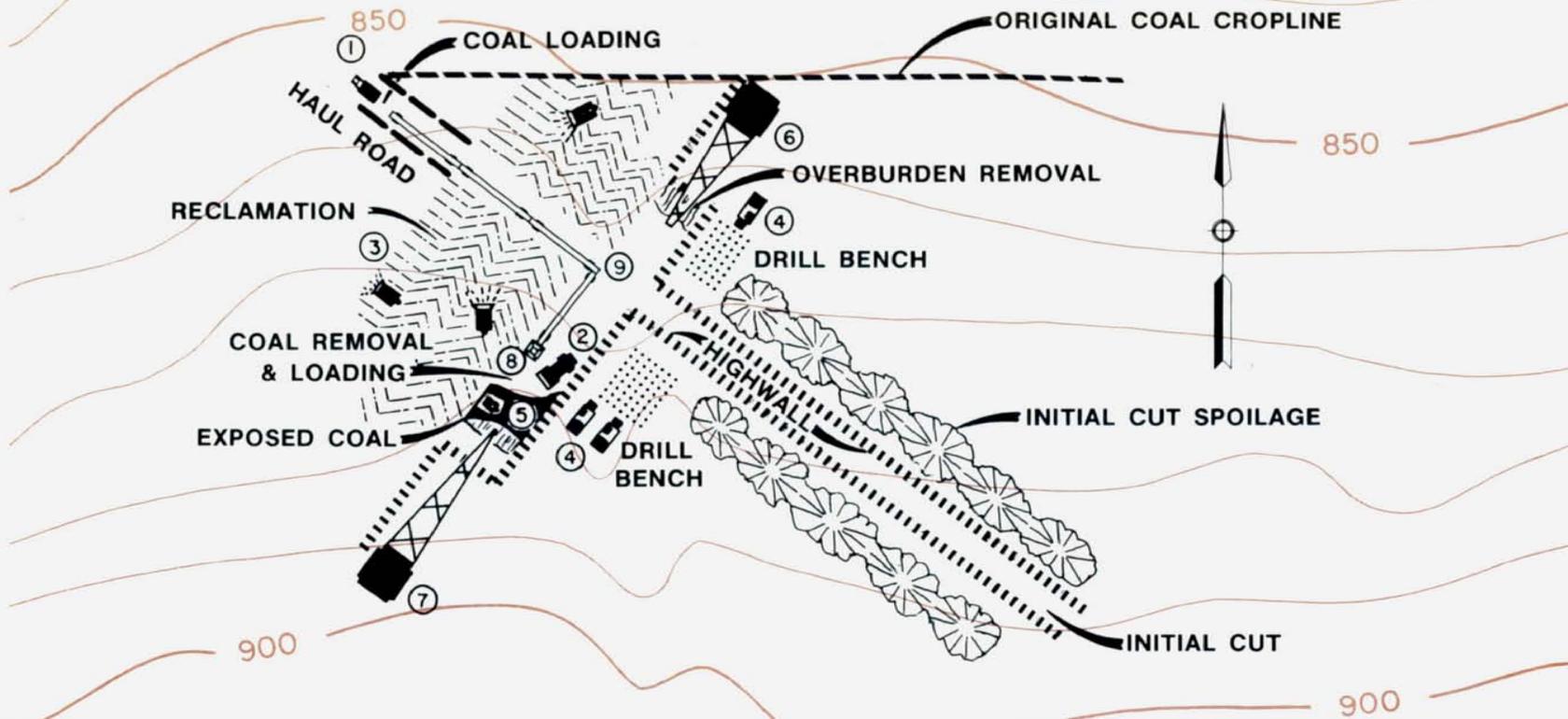
Dragline construction, or availability, should be scheduled to have one unit operational for key cut development as the second unit is brought on line. The first machine will excavate the key cut diagonally across the property from the cropline to the highwall limit. Spoil will be cast to both sides to equalize rehandle during full-scale operations as shown in Figures 18 and 19. This will facilitate sequencing the advance of both draglines. Coal loading and hauling will be phased in with the key cutting. As the coal face is advanced, a level haulage road will be established to prevent a constant haul on a sloped ramp.

At the end of the key cut, the first dragline will deadhead to the cropline and start primary stripping. Proper scheduling should have the second dragline operational by this time and slightly into its first cut.

### **Overburden Handling**

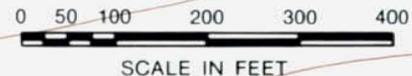
Primary stripping units will be draglines working on opposite sides of the central haulage way. An anticipated work schedule, for the draglines, is 3 shifts per day, 300 days per year. Most large draglines are limited to operating grades of less than 10°. By using cuts on a diagonal to the maximum ground slope, this problem should be alleviated. First cut spoil will be cast on the up-dip side out of the pit area. This material will be stabilized and rehandled, after completion of mining, to fill the central haul ramp.

Mining will advance from the outcrop diagonally down-dip by a series of parallel cuts, with one dragline cut slightly in advance of the other. This staggering will facilitate uniform coal production during the time each machine spends deadheading. After the first cut, all overburden will be



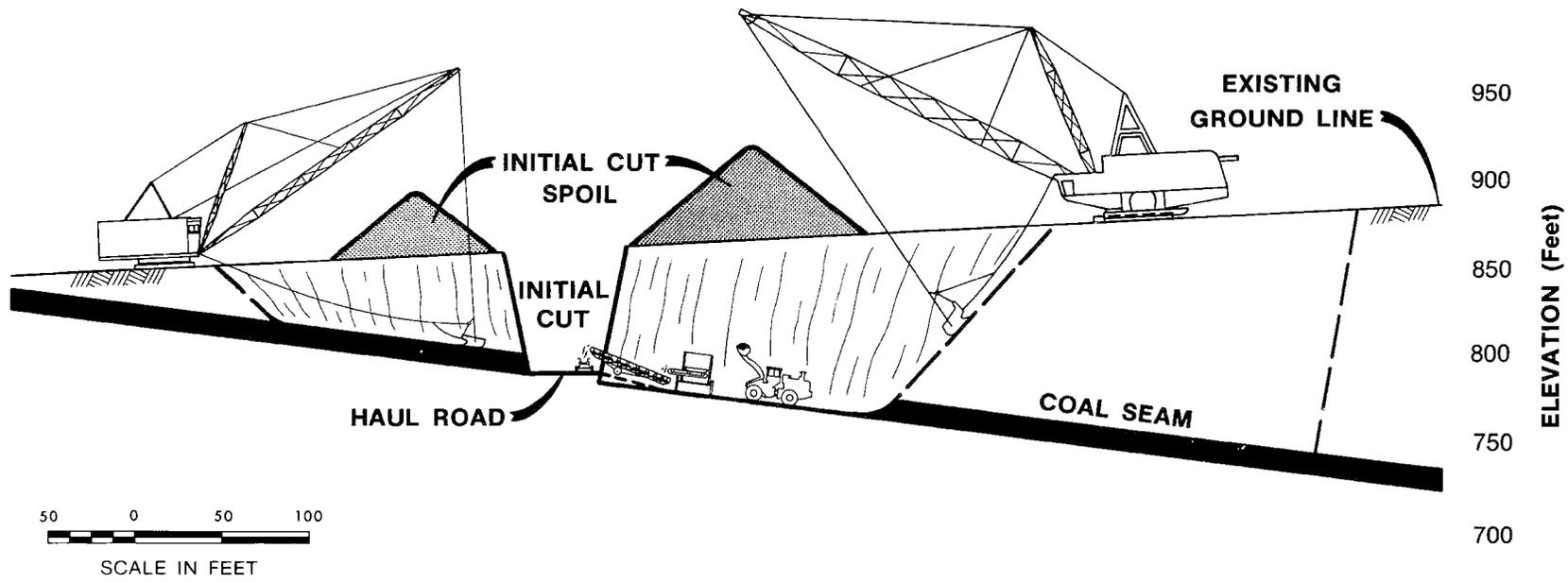
**EQUIPMENT IDENTIFICATION**

- |                      |                     |
|----------------------|---------------------|
| ① COAL HAULAGE TRUCK | ⑥ 12-YD. DRAGLINE   |
| ② FRONT-END LOADER   | ⑦ 36-YD. DRAGLINE   |
| ③ DOZER              | ⑧ HOPPER FEEDER     |
| ④ OVERBURDEN DRILL   | ⑨ PORTABLE CONVEYOR |
| ⑤ COAL DRILL         |                     |



**CONCEPT 4 - DIAGONAL MINING/TANDEM DRAGLINES**

FIGURE 18



**CONCEPT 4 - TYPICAL CROSS SECTION  
OF MINING OPERATIONS**

**FIGURE 19**

- 111 -

spoiled up-dip into the mined out area. Spoil stability problems should be minimized by mining on the diagonal. Total in-pit rehandle of the key cut spoil will eliminate most offsite spoil disposal problems.

### **Coal Loading and Hauling**

Because coal loading and hauling will alternate between pits and will have to progress fairly rapidly, a flexible system is necessary. To meet these requirements, front-end loaders will be teamed with mobile conveyor units. Coal loading and hauling will be scheduled for 1 shift a week, 50 weeks per year.

As with all concepts, costs and production schedules were generated reflecting drilling and blasting to fragment coal prior to loading.

### **Reclamation**

Excluding the key cut area, reclamation will be kept concurrent with mining. Dozers will strike and regrade the dragline spoil piles. Scrapers, working in a closed loop, will redistribute topsoil on the regraded areas as they remove it from the unmined area. When the mine advances beyond the halfway point, reclamation activities will be designed to permit redistribution of spoil from the unreclaimed areas into the final pit and lower haul road once mining is finalized. All but cropline spoil will be contained in the pit, and swell should provide sufficient material to return the site to approximate original contour. Dozers and scrapers will move the stockpiled cropline cut material into the central key cut after mining.

Revegetation options with this system are diverse. Site specific climatic factors will be the principal controlling factor. A return to a diverse native species composition will be the most likely revegetation plan from a legal standpoint.

## General Concept Analysis

Current mining laws encourage on-site containment for surface coal mines. With this system, all overburden material not directly cast into the pit is rehandled into the central key cut to finalize reclamation. While this necessitates maintaining limited operations after the coal has been extracted, it does reduce, almost to nothing, the off-site effects of mining.

The series of diagonal cuts enhance the application of this mining system to coal seams dipping greater than  $10^\circ$ . Haulage up the central key cut ramp is at a grade about one half of the true dip, which allows greater flexibility in haulage units. Diagonal dragline cuts permit the mining of areas where the true ground slope exceeds the recommended operating parameters for most draglines. This is a distinct economic advantage, because in a large scale open cut system, few overburden removal systems can out-produce a dragline. Also, by mining diagonally, most spoil stability problems that could be expected from a similar strikeline system will be overcome. Coal production should be at a fairly high level, depending upon seam thickness. By using a system of alternately loading from each pit, a uniform coal recovery rate is maintained.

Spoil rehandle, both cropline cut and key cut area, is one constraint on this concept. However, the material to be rehandled represents a small percentage (10%) of the total overburden volume. Additionally, the economics of hauling, storing and maintaining a disposal site preclude this as an option. Up-dip haulage will affect the overall truck efficiencies, but the diagonal ramp will keep grades minimized.

Until the mine advances beyond the halfway point there could be a problem with water accumulation in the lower pit. While the degree to which the operation is affected will be site specific, because of climatic considerations, periodic pumping should adequately handle any problems. Another site specific factor that will require attention is the slope stability aspects of the up-dip highwall along the key cut. Because this cut

will remain open for the life of the operation, care will be required in the overburden geologic analyses.

Table 8 provides a synopsis of key economic and production statistics abstracted from more detailed data contained in the Appendices.

**TABLE 8**  
**CONCEPTS 3 AND 4 - ECONOMIC PARAMETERS**

**ANNUAL OPERATING COSTS**

Manpower	\$ 3,643,000
Operating Supplies (Conventional)	4,573,000
Operating Supplies (Conveyor)	55,000
Auxiliary Cost	6,667,000
Indirect Cost	1,241,000
Fixed Cost	527,000
Depreciation	2,993,000
<b>TOTAL ANNUAL OPERATING COST</b>	<b>\$19,699,000</b>
<b>ANNUAL COAL PRODUCTION</b>	<b>1,820,000 Tons</b>
<b>OPERATING COST PER TON</b>	<b>\$10.82</b>
<b>DISCOUNTED PRICE PER TON (15%)</b>	<b>\$13.26</b>

## **DIPLINE MINING/MULTIBENCH HAULBACK - CONCEPT 5**

### **General**

This concept presents a down-dip multiseam haulback mining system for use in areas where coal dips are generally less than 20°. In this scenario, two seams (both 9 feet in thickness) are being mined to their economic limit (150 feet deep), with the pit advancing along the strike. Spoil from initial site development will be placed in an engineered fill adjacent to the mine. By containing all remaining overburden material in the pit area, reclamation is concurrent, and spoil swell will allow complete reclamation of the pit with minimum rehandle.

The upper seam will be mined using a hydraulic excavator/truck team operating on the original ground surface. This will eliminate up-grade haulage associated with in-pit loading. A second lift, taken with a front-end loader/conveyor system, will expose the lower seam for loading. A front-end loader/truck team is used for coal loading and hauling. All of these activities are illustrated in Figure 20.

### **Site Development**

Clearing and grubbing operations will be designed around site specific considerations. Where brush or timber are present, 500 horsepower bulldozers will be used to windrow the vegetation. Two 21 cubic yard self loading scrapers will remove and stockpile topsoil from the pit development and spoil disposal areas. Some of the stockpiled topsoil will be redistributed over the fill. Once initial site development work is completed, the scrapers will operate on a closed loop system removing topsoil in advance of mining and spreading it over the regraded spoil.

Drill benching, when required, will be accomplished with 500 horsepower dozers. When terrain conditions permit, the scrapers will be used for drill bench preparation. The upper bench and first cut on the



lower level will be drilled with a 9 inch air rotary vertical drill. ANFO will be the primary blasting agent with hole spacings and powder factors based on site specific overburden characteristics.

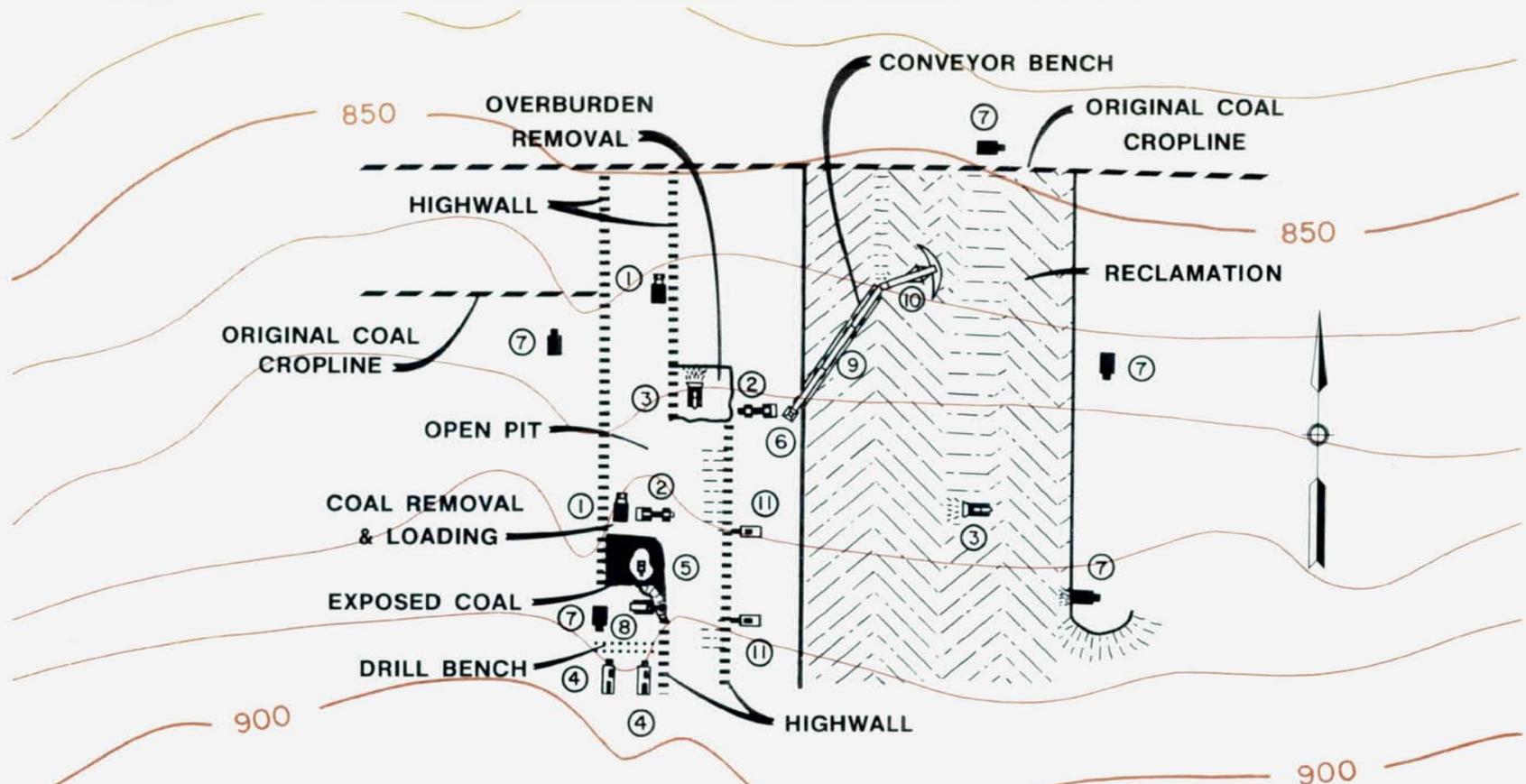
Excavation of the first cut will be developed from the cropline to the highwall limit using a hydraulic excavator/truck team. To permit coal haulage up the coal dip, this bench will be advanced 1½ cuts before the second lift over the lower seam is started. All development spoil will be transported to a fill area for disposal, providing spoilage area for subsequent haulback activities. Overburden above the bottom seam will be removed using a front-end loader/conveyor system, taking advantage of the comparative operation cost advantage over trucks. Ideally, the spoil disposal area will be immediately adjacent to the mine, allowing dozers to push the spoil from the end of the radial stacker toward the advancing truck haulback fill. When the second cut off of the lower coal seam has been excavated to the highwall limit, both excavating teams will begin haulback operations with spoil all placed into the mined out pit. Figures 21 and 22 depict the relationship of individual working benches and respective equipment deployment.

### **Overburden Removal**

Two separate drilling systems will be used at this mine. A 9 inch air rotary vertical drill will be used on the upper lift and to develop the first cut on the lower lift. On successive advancing lower cuts, 9 inch horizontal drills will be employed. This will allow drilling operations to proceed on the lower bench without affecting work on the upper bench.

A 10 cubic yard hydraulic excavator will work to four 50 ton rock haulers to excavate the upper bench. All spoil from the first 3½ cuts will be placed in an engineered spoil disposal fill. This will be adjacent to the development area. The fill will be started at the outer limit and advanced toward the pit. When the bottom lift is started, a 12 cubic yard front-end loader will load and carry fragmented overburden to the conveyor spoil

- ◀ FIGURE 20 - Artist's Sketch of Concept 5 -
- ◀ Dipline Mining/Multibench Haulback.



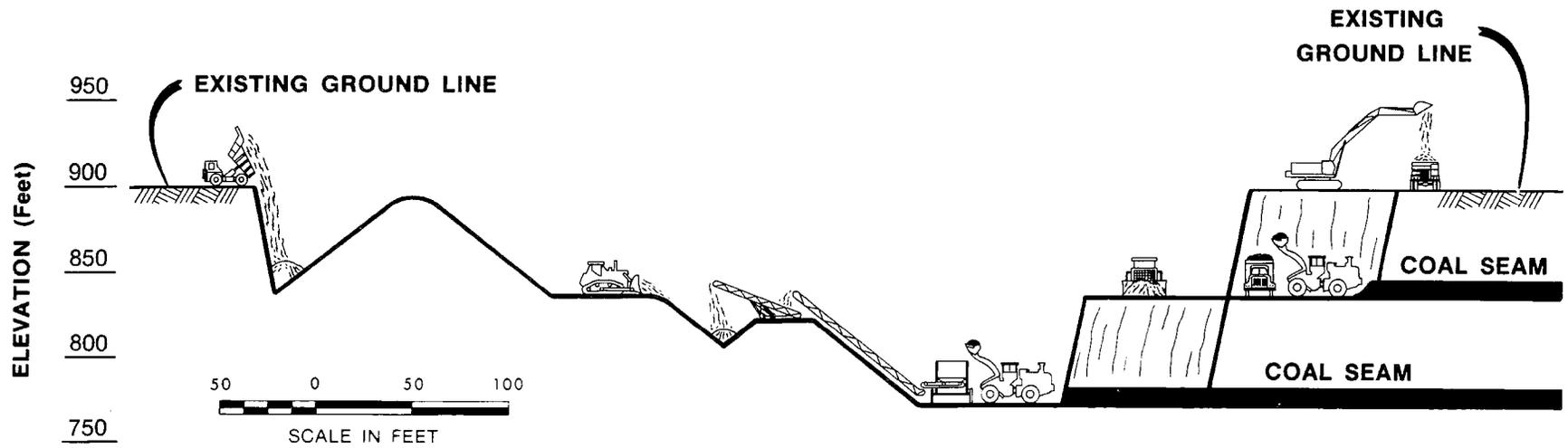
**EQUIPMENT IDENTIFICATION**

- |                      |                       |
|----------------------|-----------------------|
| ① COAL HAULAGE TRUCK | ⑦ OVERBURDEN TRUCK    |
| ② FRONT-END LOADER   | ⑧ HYDRAULIC EXCAVATOR |
| ③ DOZER              | ⑨ PORTABLE CONVEYOR   |
| ④ OVERBURDEN DRILL   | ⑩ RADIAL STACKER      |
| ⑤ COAL DRILL         | ⑪ HORIZONTAL DRILL    |
| ⑥ HOPPER FEEDER      |                       |



**CONCEPT 5 - DIPLINE MINING/MULTIBENCH HAULBACK  
MINE LAYOUT PLAN**

FIGURE 21



### CONCEPT 5 - TYPICAL CROSS SECTION OF MINING OPERATIONS

FIGURE 22

handling system with a radial stacker at the discharge end. First and second cut spoil from the lower seam will be conveyed to the outcrop, and dozers will establish the fill and advance it toward the truck dump fill. Design of the disposal area will be centered on storing the total volume of spoil to be excavated during pit development. Topsoil will be spread over the completed fill, and the area revegetated.

At full scale, each bench will be excavated down-dip to the highwall limit with the mine advancing along the strike. Spoil from the upper bench will be hauled to the middle of the initial highwall and dumped into the mined out area. The conveyor will advance a spoil pile from the cropline down the pit floor. Material will be stacked at least to the original ground line. When the conveyor approaches the truck dumped spoil, a dozer will bench the pile and the stacker will continue to place spoil to the original ground elevation until it reaches the end of the pit. Both truck dumping and conveyor handling will be scheduled to avoid interference and allow total refilling of the pit. When the spoil reaches the original ground line, or above, the fill will be advanced with the mine. Truck and dozer action will provide some compaction of the spoil to overcome swell problems.

It will be possible to store excess spoil on the bench. By backstacking on the refilled area, the only spoil that needs to go into the engineered fill is the material from the pit development work. As the mine nears completion, spoil from the final cuts will be stored on the haulback area and dozed to fill in the last pit. Overall, there might be a slightly higher final land surface elevation, however, the trucks and dozers should provide sufficient compaction elevation to minimize this.

### **Coal Loading**

Coal will be drilled and blasted to provide necessary fragmentation. A 7.5 cubic yard front-end loader will be used for coal removal with five 50 ton trucks for haulage. This system will provide

flexibility for working the lower pit area and maintaining coal production with the mine's advance.

### **Reclamation**

All reclamation at this mine will be concurrent with the pit's advance. The spoil disposal area will be designed for a maximum 30 foot lift height with 2:1 outslopes. As the fill is built, from both ends toward the center, topsoiling and revegetation will be ongoing. By using a haulback system, nearly all spoil is contained in the pit and backfilling to approximate original contour can be achieved. Both overburden removal teams are well suited to segregation and special handling of toxic or acid producing strata. Trucks can be directed to special dump points while radial stackers can be positioned to selectively place spoil. Topsoil from the final cuts will be stockpiled for replacement when the dozers have refilled the pit.

Post-mining land uses will not be restricted in any way. If spoil swell is excessive and material must be stacked on the backfill, the overall surface configuration should not interfere with agricultural or grazing land uses.

### **General Concept Analysis**

Enhanced coal recovery due to potential economic advantages and concurrent reclamation are two benefits this concept affords. Once initial pit development spoil has been placed in the engineered fill, all spoil is contained within the pit. The backfill area will advance at about the same rate as the mine. Swell problems will be reduced, or negated, by backstacking on the fill. As mining is finalized, the spoil swell should have been designed to catch up with the operation and advance spoil placement close to the last cut. Excess material will be stored in lifts on the backfill and dozed into the last cut. Because this will be a down grade,

short push, the dozers will be working at optimum production. Scrapers will assist in the final regrading and spread stockpiled topsoil. Final reclamation work should not extend significantly beyond the mine's productive life.

Both overburden handling systems are flexible enough to overcome toxic or acid producing overburden problems. The truck haulage units can descend the lower pit ramp to place these materials where they will be adequately buried. By using the front-end loader in a load-carry-dump cycle, without the conveyor, the same objective can be achieved, if overburden conditions above the lower seam warrant specialized material handling.

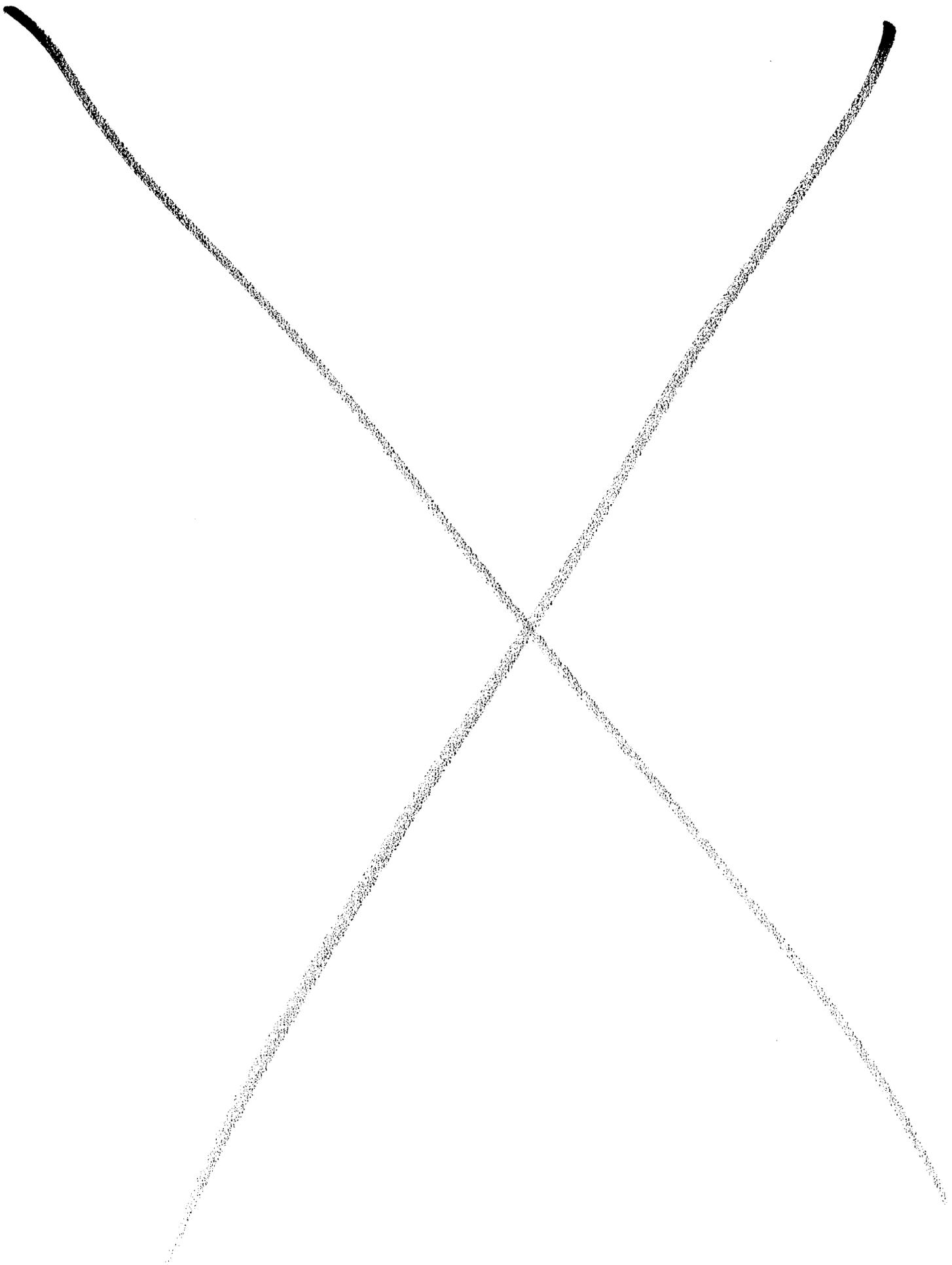
Coal seam dip will influence coal haulage out of both pits. In situations where the pitch exceeds about  $10^{\circ}$ , haulage will be seriously affected. To increase the utility of this concept, conveyors could augment the coal trucks. Over the relatively short distances involved, they will compare with trucks in both economy and productivity and will permit mining of seams dipping to  $10$  to  $25^{\circ}$ . At the cropline, the coal will be loaded into the trucks for transport to the stockpile. A system using both conveyors and trucks would be particularly applicable in areas where the coal dip varies within the pit.

Any time spoil has to be placed in an engineered fill, there are additional costs and off-site impacts that must be mitigated. However, the use of an off-site spoil disposal area increases the utility and flexibility of this concept without significantly increasing costs or impacts. Care must be taken to avoid building the fill over coal reserves, but by locating the fill immediately adjacent to the mine, haulage costs are minimized. The fact that a one lift fill, with good compaction and reclamation, is to be used reduces the off-site impacts from erosion and land use aspects.

The following summary indicates low costs and high production with the Dipline Mining/Multibench Haulback Concept. Operating costs reflect the advantages presented by conveyor haulage of overburden and level haulage from the hydraulic excavator.

**TABLE 9**  
**CONCEPT 5 - ECONOMIC PARAMETERS**

<b>ANNUAL OPERATING COSTS</b>	
Manpower	\$ 4,007,000
Operating Supplies (Conventional)	3,541,000
Operating Supplies (Conveyor)	23,000
Auxiliary Cost	6,922,000
Indirect Cost	1,136,000
Fixed Cost	354,000
Depreciation	2,530,000
<b>TOTAL ANNUAL OPERATING COST</b>	<b>\$18,513,000</b>
<b>ANNUAL COAL PRODUCTION</b>	<b>1,900,000 Tons</b>
<b>OPERATING COST PER TON</b>	<b>\$9.74</b>
<b>DISCOUNTED PRICE PER TON (15%)</b>	<b>\$11.42</b>



## **STRIKELINE MINING/TERRACE PIT APPROACH - CONCEPT 6**

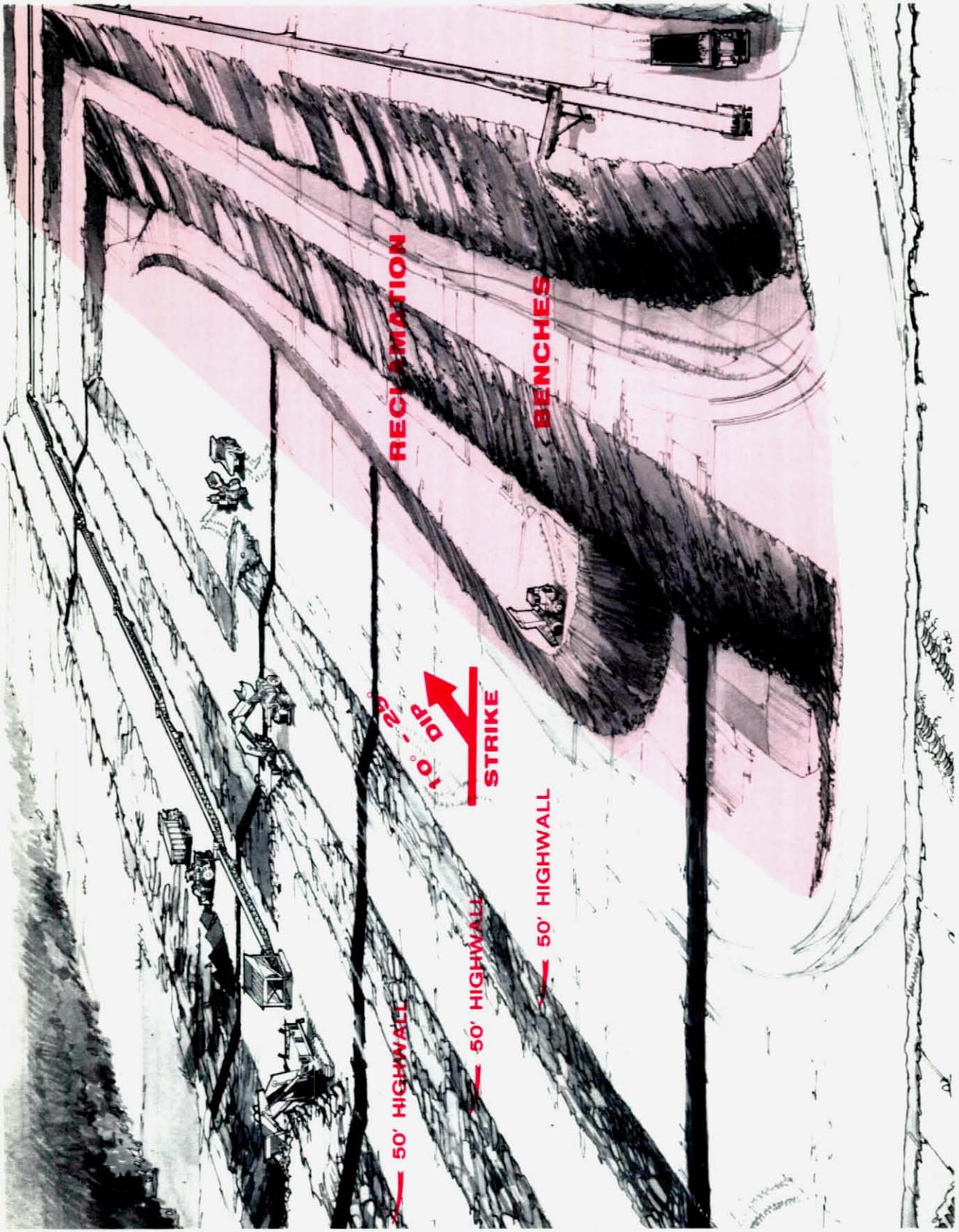
### **General**

Concept 6 proposes a strikeline terrace pit approach utilizing a mix of stripping/loading units (see Figure 23) to handle multiple moderately dipping coal seams under a horizontal land surface. The primary stripping units will be, at first, two 10 cubic yard hydraulic excavators loading into trucks and a front-end loader also loading trucks. After the initial series of terraces has been developed, a hydraulic excavator/conveyor system will operate on the highest bench as the primary overburden stripping unit. After this stage is reached, a 7.5 cubic yard front-end loader will remove and load coal into 50 ton trucks. The assumed land surface is gently sloping with four coal seams dipping 18° to 25° relative to it. This mine concept requires that all aspects of its operation work on a full time schedule of three shifts, six days per week for 300 days a year. The three shift schedule is implemented to attain annual production goals while equipment choices represent potential new applications with possible economic advantages.

### **Site Development**

Normal clearing and grubbing operations will be carried out using 524 horsepower bulldozers. Topsoil will be removed, segregated and stockpiled by a pair of 21 cubic yard scrapers in conjunction with the bulldozers.

Initial cut will be made to the maximum width (1000 feet) of the final pit using a 10 cubic yard hydraulic excavator and 50 ton trucks to remove the overburden to the required depth for the terrace, which will eventually become the conveyor bench. A second terrace level will then begin and progress along the strike following the topmost bench. When



RECLAMATION

BENCHES

10° - 25°  
DIP  
STRIKE

50' HIGHWALL

50' HIGHWALL

50' HIGHWALL

sufficient progress has been made a third deeper terrace will be started with the 12 cubic yard front-end loader and the hydraulic excavator to remove the overburden. Trucks will be used to haul overburden out of the pit for storage elsewhere. At this stage the shift of equipment will be made to bring the hydraulic excavator/conveyor system into production on the top bench.

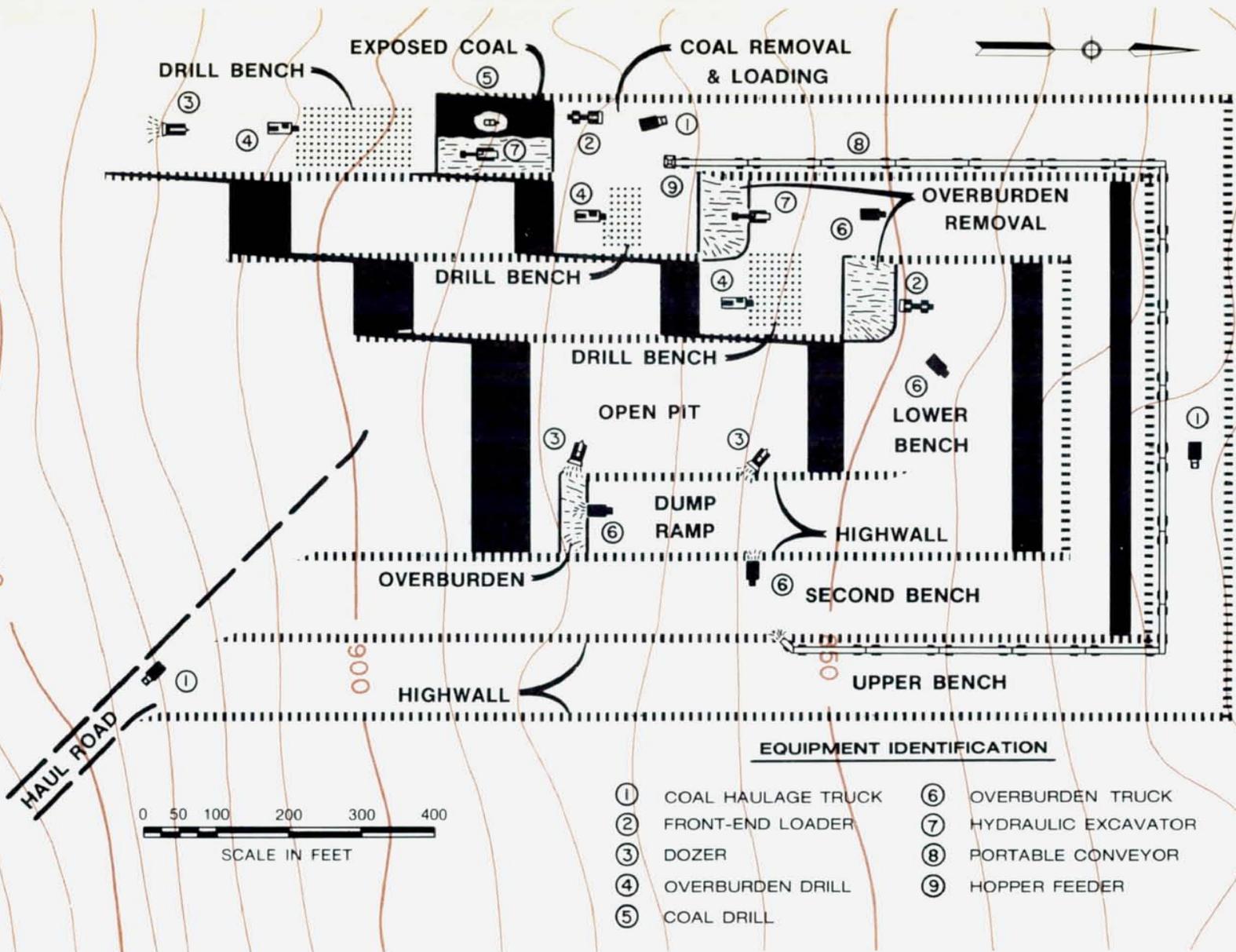
As shown on the plan map, Figure 24, haul roads will be maintained along three sides of the terrace pit. The lowermost pit coal haul road will be laid out directly across the pit floor and up the grade at the corner of the pit. The second terrace haul road will extend from the active face of the pit around three sides atop the advancing spoil from its own bench. It will enter the same corner haul ramp used by all pits but at a higher level than the lower pit. The top bench haul road will be placed outside the conveyor overburden distribution system and will progressively follow the pit as it advances. It too will enter the corner common haul ramp near the initial land surface.

### **Overburden Handling**

The primary overburden stripping unit on the upper terrace bench will be a hydraulic excavator feeding a conveyor belt which will carry spoil around the open pit to the mined-out pit area. The conveyor will have a spoil tripper to distribute the spoil from the conveyor system. A 10 cubic yard hydraulic excavator truck haul system will be used on the second bench. This excavator will be used to remove shot overburden and load a fleet of three 50 ton dump trucks which will haul spoil to the trailing side of the second bench where it will be dumped into the third level of the pit. The lowermost pit will have a 12 cubic yard front-end loader for overburden removal and for loading 50 ton trucks which will haul spoil to the opposite side of the pit for backfilling and compaction.

Although equipment selections take advantage of low cost conveyors for the longest haul and flexible front-end loaders for

- ◀ *FIGURE 23 - Concept 6 - Strikeline/Terrace Pit*
- ◀ *Mining Approach.*



**CONCEPT 6 - STRIKELINE MINING/TERRACE  
PIT APPROACH**

FIGURE 24

- 132 -

overburden removal in the lower pit where some direct spoil haulage can occur, this concept can be implemented with a variety of equipment types. In-depth engineering and overburden analyses should precede equipment purchase and final pit layout.

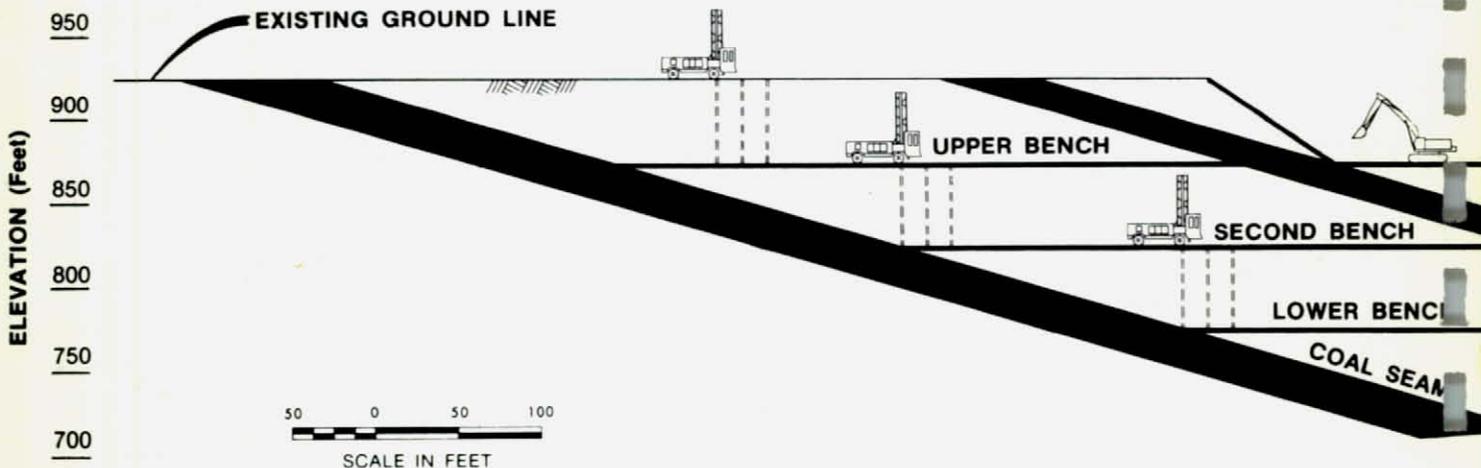
Initial pit development will proceed in three stages. The first will consist of the initial box cut to be made by the hydraulic excavator and 12 cubic yard front-end loader. Spoil from this cut will be truck hauled to a storage area. When this cut is sufficiently developed, the second level will be opened with the hydraulic excavator while work continues on the first bench. Both pits will proceed until sufficient spoil has been removed to open the bottom pit. During the second phase the conveyors will be erected and begin work on the topmost bench and both the front-end loader and hydraulic excavator will open the third pit. The use of both pieces of equipment will enlarge this lower pit to quickly reach the proper size. At the third phase on hydraulic excavator will be moved to its bench and the 12 cubic yard front-end loader will remain to excavate the lower terrace. While individual operating faces will be advanced down-dip, the entire pit will proceed along the strike of the coal. Until this phase is reached, all the spoil will be hauled away from the pit for storage. Spoil rehandle will not be necessary until final pit closure and reclamation begins.

### **Coal Loading and Transport**

The coal will be drilled and shot. A 3 inch drill capable of slant drilling will be used. ANFO is to be used as a blasting agent for the coal. A 7.5 cubic front-end loader will load coal into five 50 ton dump trucks used only for coal haulage. Haul units will ramp out of the pit at the far end of the reclamation side of the operation.

## Reclamation

Once the full three phase operation is established, spoil will be placed into the pit opposite the active working faces. As the pit advances it will fill itself in until the bottom pit is eventually terminated. This process will continue until the mine is exhausted. Spoil initially removed can be placed into the filled areas and regrading commenced before the final closure of the mine. Regrading will be done with bulldozers and scrapers to original contour as the pit is filled in from rehailed spoil. Topsoiling will begin as soon as final regrading is completed. The final cut will be made by the hydraulic excavator/conveyor team, since the other two benches will have completed their operations and been buried earlier. The final cut should be easily filled by pushing the last spoil back into the cut since it will have been placed immediately adjacent to it. This final cut will then be regraded and topsoil replaced upon it for revegetation.

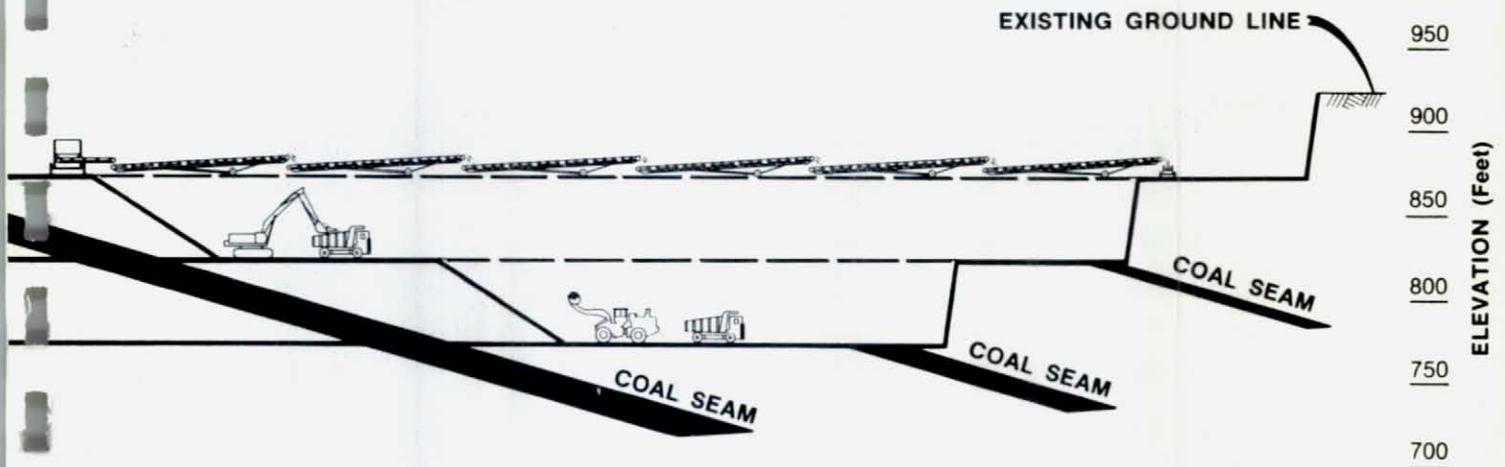


CONCEPT 6 - TYPICAL CROSS

## General Concept Analysis

In many of the western coal states, there are extensive areas where multiple seams are present, but the coal dips preclude extensive development. Current mining practices are usually limited to one, or at most two, strikeline cuts along each seam. By using a terrace pit approach, enhanced coal recovery of three or more seams can be realized without increasing mining costs or impacts.

The equipment fleet illustrated is only one of many feasible alternatives using readily available mining machinery. This particular scenario affords an extremely wide range of flexible equipment applications. At full scale development, this type of operation would have a high coal production. Additionally, if the market constraints were to change, another lower terrace could be initiated without extensive realignment of existing operations. Figure 25 indicates that this expansion could be accomplished without creating operating constraints often presented by confined working conditions.



**SECTION OF MINING OPERATIONS**

**FIGURE 25**

Except for the overburden excavated during pit development, all spoil is contained in the pit, and reclamation is concurrent. Latitude is available for special reclamation objectives or landforming to meet selected post mining land uses. Additionally, this system is well suited to special handling or segregation of toxic or plant growth-inhibiting strata.

Terrace pit mining is very capital intensive and requires continuous operation and fairly extensive reserves to offset initial investment costs. Detailed premining engineering studies and extensive site development work are necessary. A storage area for the initial spoil is required close by. Unless a variance to the approximate original contour regulations of PL 95-97 can be obtained, the initial cut material may have to be rehandled to fill the final pit.

In the areas where this system has the most potential for application, faulting can be a serious problem. Detailed geologic studies will reduce the chances of undetected fault zones interrupting mining.

**TABLE 10**  
**CONCEPT 6 - ECONOMIC PARAMETERS**

<b>ANNUAL OPERATING COSTS</b>	
Manpower	\$ 4,019,000
Operating Supplies (Conventional)	4,118,000
Operating Supplies (Conveyor)	83,000
Auxiliary Cost	6,927,000
Indirect Cost	1,233,000
Fixed Cost	377,000
Depreciation	2,787,000
<b>TOTAL ANNUAL OPERATING COST</b>	<b>\$19,544,000</b>
<b>ANNUAL COAL PRODUCTION</b>	<b>1,900,000 Tons</b>
<b>OPERATING COST PER TON</b>	<b>\$10.29</b>
<b>DISCOUNTED PRICE PER TON (15%)</b>	<b>\$12.07</b>

## COMPARATIVE EVALUATION

Pertinent production and economic statistics for both case history mines and improved concepts are summarized in Tables 11 and 12. Examination of the exhibit shows that Case Histories 1 and 3 possess the economic edge for both operating costs and selling price. While this could be indicative of a good stripping ratio, further study of the table illustrates that these two case histories also possess the lowest cost of excavation (on a cubic yard of overburden basis). Particularly in Case History 1, these advantages can be attributed to the type of mining scheme being utilized at the operations. Utilizing a single haulage route throughout the mine life and minimizing dragline deadheading, Case History 1 (a strikeline/tandem dragline operation), although containing minor problems, is an efficiently run mine site. This is one of the prime reasons why several of the proposed concepts contain tandem dragline units and single life of mine haul roads.

Further scrutiny of Table 11 delineates Case History Mines 2 and 5 as the most expensive operations. Again this is evident from a careful study of the mine sites. Mine 2 with its haulback approach contains many poorly designed queue points in its haulage system, creating excessive delay time for the excavation units — thus decreasing production and increasing costs. Case History 5's high costs can be attributed to the severe pitch of the coal seam worked at the mine. As brought to light in an earlier discussion, only two cuts can be mined economically.

Similar evaluations of Table 12 show surface dozer Concepts 2 and 5 as the most economical. This can partially be attributed to the system flexibility gained from use of mobile equipment in the mining scenarios.

When comparing Tables 11 and 12, it appears that the majority of concepts have fewer economic advantages compared to existing operations. It should be remembered that the typical mine site utilized in the systems analysis reflects a "worst case situation". If these concepts

**TABLE 11**  
**CASE HISTORIES OPERATING PARAMETERS**  
**COMPARATIVE EVALUATION CHART**

<b>CASE HISTORY MINES</b>	<b>ANNUAL COAL PRODUCTION</b>	<b>ANNUAL OPERATING COSTS</b>	<b>CAPITAL REQUIREMENT</b>	<b>OPERATING COST PER TON</b>	<b>DISCOUNTED SELLING PRICE PER TON</b>	<b>COST OF EXCAVATION/ BANK CUBIC YARD</b>
1	3,200,000 TONS	\$24,365,000	\$25,298,000	\$ 7.61	\$ 8.78	\$1.40
2	500,000 TONS	\$ 7,274,000	\$ 7,922,000	\$14.55	\$16.93	\$2.25
3	2,330,000 TONS	\$22,516,000	\$40,333,000	\$ 9.66	\$12.16	\$0.99
4	1,200,000 TONS	\$12,839,000	\$19,968,000	\$10.70	\$13.06	\$1.42
5	80,000 TONS	\$ 2,576,000	\$ 3,888,000	\$32.20	\$39.20	\$1.64

**TABLE 12**  
**CONCEPT OPERATING PARAMETERS**  
**COMPARATIVE EVALUATION CHART**

CONCEPT	ANNUAL COAL PRODUCTION	ANNUAL OPERATING COSTS	CAPITAL REQUIREMENT	OPERATING COST PER TON	DISCOUNTED SELLING PRICE PER TON	COST OF EXCAVATION/ BANK CUBIC YARD
1	1,820,000 TONS	\$19,761,000	\$30,353,000	\$10.86	\$13.28	\$2.15
2	1,900,000 TONS	\$17,147,000	\$19,211,000	\$ 9.02	\$10.62	\$1.91
3 & 4	1,820,000 TONS	\$19,699,000	\$30,522,000	\$10.82	\$13.26	\$2.14
5	1,900,000 TONS	\$18,513,000	\$21,222,000	\$ 9.74	\$11.42	\$2.06
6	1,900,000 TONS	\$19,544,000	\$22,623,000	\$10.29	\$12.07	\$1.52

were implemented on a site similar to those observed at Case Histories 1 and 2, a significant reduction in operating costs would be experienced. A summary discussion of environmental and health/safety considerations can be found in the conclusions and recommendations section of this report.

## CONCLUSIONS AND RECOMMENDATIONS

During the course of this study, a number of mining operations were visited and subsequently evaluated for the following parameters:

- Mining and Economics
- Health and Safety Considerations
- Operational Problems
- Production Goals

Analyses of several of the currently practiced systems revealed particular operational deficiencies in the handling of coal where extraction approaches create in-pit haul roads running with the dip. Other observations delineated the concerns associated with dragline mining in variable cover situations. Restricted reach capabilities and mine designs forcing up dip spoilage, have promoted in many cases low productivity, reduced reserve recovery, and high costs. Thus it became evident early in the study that concept designs had to incorporate techniques aimed at alleviating these concerns.

Adhering to this criteria, representative mine sites employing new mining concepts were developed. These scenarios were created to operate under a variety of conditions yet be specific enough to allow an operator to select the proper scheme for a site. Dual dragline schemes, for instance, were created to operate on larger properties where property constraints allow a sufficient reserve base and areal extent to practically exploit the full utility of the stripping units. These techniques are designed to be implemented in generally flat terrains with predominately deeper cover. The use of Dual units allows each drag to operate within its optimum digging depth, increasing the reserves that may be efficiently extracted. Three different layout configurations - dipline, diagonal and strikeline - facilitate the selection of the appropriate method depending on the dip of the coal. Gentler dips (8 - 10°) are effectively mined with the dipline method, while moderate dips (10 - 18°) require diagonal extraction and the

upper range (18 - 25°) necessitates strikeline. The upper limits of these approaches are based on the grade restriction (10°) imposed on mobile equipment for efficient haulage. Conveyors which can operate up to 18° slopes can extend these limits if employed for coal haulage.

Three mobile equipment scenarios were also conceptualized during this study. These schemes, offering greater flexibility and latitude in sloped or rolling terrain, can be employed on a range of dipping seams. However, as they are mobile equipment techniques, extremely high cover and correspondingly high strip ratios can reduce productivity and increase costs.

Although the economics of the concepts did not demonstrate a real savings as compared to the case history sites, the production advantages were somewhat significant in several cases. Additionally, the worst case site chosen for concept evaluation was primarily responsible for the high costs.

From an environmental standpoint the haulback approaches (concepts 5 & 6) appear to be the most desirable offering the capability to selectly isolate and handle overburden material, clearly a prerequisite in prime farmland and toxic spoil areas. These concepts also offer concurrent reclamation, promoting minimal disturbed areas.

Health and safety assets and liabilities are essentially equal between the proposed schemes. That is, all exhibit similar capabilities to operate within the constraints of mine safety mandates. One possible exception is the dragline schemes where excessive cover may create extremely deep highwalls. The mobile approaches with the multiple lift configurations reduce this safety hazard.

Based on an evaluation of these proposed concepts it appears that concepts 5 & 6 and one of the dual dragline configurations demonstrate enough merit to be studied further. Each of the scenarios offers unique advantages for site specific implementation. Thus, it is

recommended that future effort be directed toward development of detailed plans and specifications for possible field demonstration of these techniques. These plans and specifications should include complete details on technique implementation, equipment selection and site design. Detailed evaluations of these three schemes should be conducted utilizing several theoretical mine sites with varying configurations, such as dip, overburden depth, strip ratio, production potential and topography. Finally, those schemes exhibiting the most potential should be further recommended for field implementation.

