DRAGLINE SIMULATION AND SELECTION

FOR

SINGLE FLAT-LYING COAL SEAMS

By

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ABSTRACT

In recent years, draglines have proved themselves to be the primary stripping machines for surface coal mining operations. Because of enormous capital requirements and associated operating costs, dragline selection and operation deserve considerable attention.

A new dragline reach equation is derived on the basis of spoil volume rather than areas of spoil from the cut-spoil diagram.

Operational methods for side casting, chop down, extended bench and pull back methods are described in detail.

Deterministic dragline simulation models are developed for simple side casting with chop down option, extended bench with chop down option, and pull back methods of stripping as an aid in dragline selection. These models are used to predict the effects of proposed changes in operating procedures on the machine's output and costs. A three dimensional approach is taken in the development of the models.

The digging position of the dragline, the horizontal swing angle of the boom, the manner in which spoiling is conducted and the obliquity of the boom foot with respect to crest of the digging face are considered in evaluating the dragline production.

A case study is included to demonstrate the application of the models in selecting a dragline for a 2.5 million ton lignite, strip mine in Texas.

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INTRODUCTION

Purpose of the Study

In recent years, the increase in energy consumption in the United States indicates that abundant use of energy is fundamental to the strength and economy of a nation. However, the proportion of the energy being supplied by imports to meet United States' demand is increasing in a pattern that makes the United States more dependent on foreign countries. The increasing awareness of energy dependence of the United States, the projected shortfall of domestic oil and gas supplies and uncertainties regarding nuclear energy, have led the mining energy companies and government agencies to concentrate their efforts on developing the United States' principle energy resource, coal.

In the process of this development, draglines became the major overburden removal equipment in surface coal mines due to their low cost per yd^3 and their flexibility. It is predicted that by 1985, 80% of western (which has two thirds of surface mineable coal reserves of the United States) coal tonnage will be produced at mines using draglines (1). Since the late sixties, draglines have been increasing in size tremendously to provide more overburden removal capability and to lower the cost. With the increase in size, draglines have become the highest capital investment item and also constitute a substantial portion of the operating cost. Therefore, the selection and operating procedures of this machine deserve considerable investigation.

Statement of the Problem

During the initial stage of mine planning and feasibility studies; selection of the stripping method and determination of the type, size and quantity of stripping equipment to achieve the desired production rate is a critical problem. The solution also affects the selection of other equipment. The overall success of the operation depends in a large part upon the selection and efficient utilization of the dragline to remove overburden.

Common practice by design engineers and equipment manufacturers has been to rely on graphical methods in dragline selection. The selection procedure consists of first matching the reach requirements and machine specifications by means of cut-spoil diagrams. These diagrams consider the cross-sectional area of dragline strip and dragline reach is determined on the basis of area of the spoil rather than volume. Bucket requirements are then determined using historic production indicies or by using a standard excavation sizing equation.

Unsatisfactory results may be obtained from using these approaches and it appears logical to take a more analytical approach such as mathematical modeling in selection.

Purpose and Scope of the Thesis

The purpose of this thesis is to review various dragline stripping methods and operating procedures, review dragline selection procedures, and then to formulate models to simulate machine operation and perform machine selection. The following methods are included: side casting with a chop down option, extended bench with a chop down option, and pull back.

The models are limited to stripping of single flat-lying seams.

LITERATURE SURVEY

Most current information concerning dragline stripping methods and selection procedures was produced by government sponsored research projects or by dragline manufacturers.

The Surface Mining Supervisory Training Program (1) by Bucyrus-Erie Company contains comprehensive descriptions of strip mining methods for single, multiple and inclined coal seams, and equipment selection. It reviews graphical and analytical methods of reach determination, bucket sizing procedures and model selection. This manual also provides a number of suggestions on methods of obtaining maximum dragline production and minimum stripping costs.

In 1975, under a United States Bureau of Mines contract, Mathematics, Inc. and Ford, Bacon and Davis-Utah, Inc. published a three-phase report entitled "Current Surface Coal Mining Overburden Handling Techniques and Reclamation Practices" (2). In this study, 159 major surface coal mines in the United States were surveyed to identify major production problem areas. As a result of this survey, background information on surface coal mining systems for the United States are presented and a description of the current surface mining practices, including dragline area mining and reclamation, are summarized.

A Skelly and Loy report entitled, "Economic Engineering Analysis of U.S. Surface Coal Mines and Effective Land Reclamation" (3) deals with economic aspects of current surface mining methods in the United States and provides unit costs of various operations.

Hagood (4) analyzed basic dragline selection procedures and cost calculations for side casting in his thesis entitled "An Equipment Analysis and Selection Procedures for Western Surface Coal Mines". In this study the method of dragline selection adhered to the procedure of matching machine specifications and production rate by means of cut-spoil diagrams and assuming an average 90^{o} swing angle with a 60 second cycle time. Operating cost of the dragline is calculated on the basis of suggested power consumption of the machine, labor, and repair and maintenance cost. Ownership cost included depreciation and charges for interest, insurance, and taxes.

Recently, Fluor Utah, Inc. and Bonner and Moore Associates, Inc. (5) developed a system of computer based simulation models for surface coal mine planning and economic evaluations under a contract with Energy Research and Development (ERDA). This 42-month project included development of three models to simulate the operation of draglines to remove overburden. Two of the models simulate the area stripping method using one single or tandem machines, while the third simulates the contour stripping method. The first simulation model is similar to Hagood's approach and considers cut-spoil diagrams to determine the range (dragline spoiling radius, dumping height and digging depth) required for the maximum, average and minimum overburden height for a given area to be mined. The model processes the dragline data file which includes specifications, operating costs, and ownership cost of all available draglines. If the machine being processed has the required range for the average conditions, then its production capability is determined on the basis of a 90^{o} swing angle and the cycle time obtained from the data file. If the dragline spoiling radius of the machine is larger than required, the swing angle is reduced by the arc cosine of the ratio of the required radius over the available radius. Cycle time for this machine is adjusted by reducing 7/30 of a second for each degree less than 90. The second dragline model, which is called the "Extended Bench Model", considers two draglines. One of the two machines works on the bench at the original ground level, and spoils the material into the previous pit area. Depth of the material to be removed by this machine is determined such that when spoil from this depth of material is leveled, the elevation of the highwall bench will be the same as the elevation of the leveled spoil surface. The second machine works on this leveled spoil bench and removes the remaining portion of the highwall and the rehandle material. Based on these assumptions, the model processes the dragline data file and determines which machine has the capability to remove the first portion of the highwall and which machine can work from the spoil side. Range requirements and production rates are calculated as previously discussed in the single dragline model. The third model, contour stripping, is similar to the first dragline model previously discussed. The difference is that dragline strips the area by following the outcrop contour line. Therefore this model considers the length of the cropline to determine volume to be removed by a dragline, then follows the same procedures and assumptions as in the first model to select the dragline.

In the Bonner and Moore models, productivity is computed without considering factors such as dragline positioning, moving patterns, manner of stripping and spoiling, and benching procedures. Therefore these models can be misleading when used to predict production rates. As a result, it might be necessary to increase machinery to meet production requirements.

D.K. Chatterjee, D. Rowlands and K.C. Siller (6) have developed a simulation model for a dragline operation in which dragline positioning, the manner of spoiling, volume of available spoil room, and the actual swing angles are considered to calculate the machine production. This model closely represents a real operation for side casting. It does not consider physical variables such as varying overburden depth for a given pit length, and various dragline positions for a set up.

Several articles have also been published in mining periodicals pertaining to dragline selection and productivity: "Selection Procedures of Goonyella" (7) discussed the calculation and reasoning behind the selection of type, size and number of draglines for a specific application. Tom Learmont (8), in his paper, "Productivity Improvements in Large Stripping Machines", discusses the effect of changes in dragline parameters such as boom length, swing power, and hoist power on dragline productivity, and makes an analysis of dragline availability and describes various causes of dragline down time.

Several other articles have also been published or presented at various meetings for dragline applications in specific areas. However, the majority of these papers provided minimal information on single seam dragline stripping operations.

SIDE CASTING

General Description of Overburden Removal

Side casting is considered to be the basic method of removing overburden and is used extensively in most surface coal mines using draglines at some time. This technique involves a dragline positioned on the overburden bank and digging down to the top of the coal while casting material into a spoil pile on the side (1). Side casting does not require any chopdown or rehandle and the machine selected has adequate reach to spoil all the material into the available spoil area. A cross section of the side casting method is shown in Figure 1.

During the initial stage of a stripping operation, dragline pits are laid off for the machine to dig. The dragline first makes a box cut opening. After the box cut is completed the dragline usually walks back (deadheads) and starts on the second cut.

It is not usually possible to establish a competent new highwall slope with the dragline positioned near the edge of the old highwall. Therefore the dragline is positioned at the inside limit of the cut to make an initial key cut. This initial cut is made to provide a stable highwall slope as well as to provide an extra free face for digging the remaining material from the cut. Figure 2 shows dragline positions for the key cut. Depending on the procedure followed by the operator

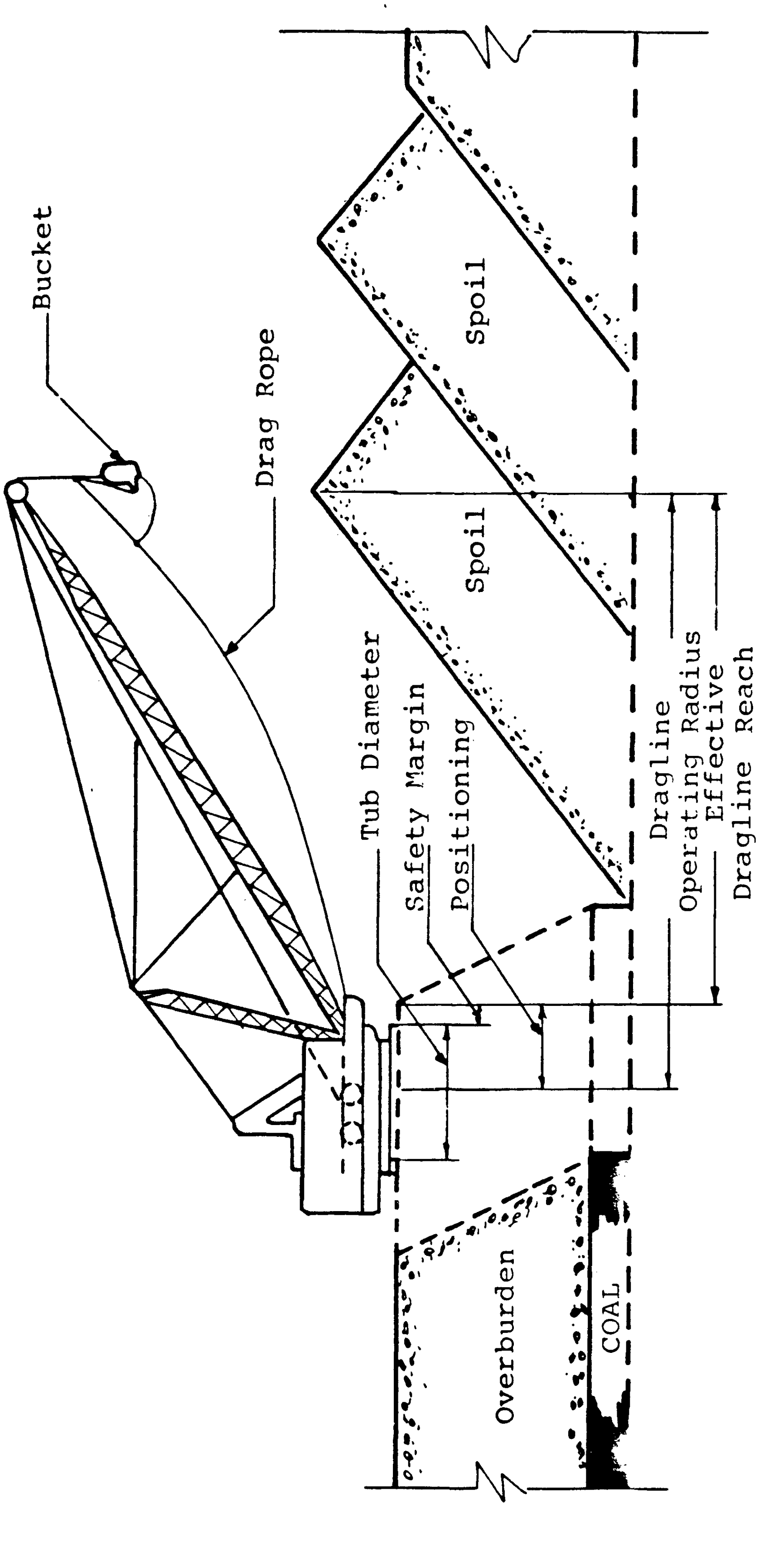


Figure 1 : Cross Sectional View of Dragline With Respect to Pit Geometry.

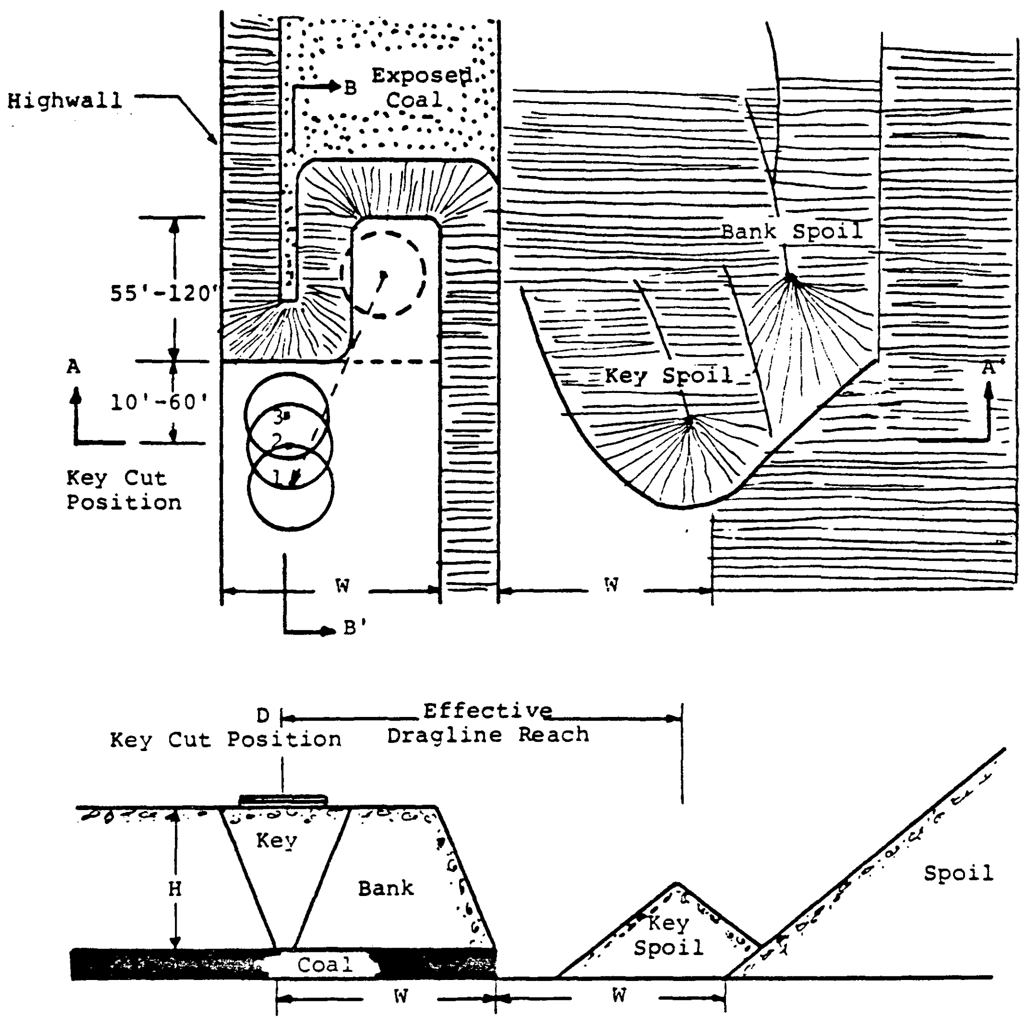


FIGURE 2. Plan and Cross Sectional Views of Dragline Movements for Making the Key Cut.

and the depth of the overburden, the dragline can either make 1 to 3 moves to complete the key cut. The initial dragline position is located about 10 to 60 feet back (15,16,17) from the projected crest of the key. Length of the key cut is approximately 55 to 120 feet in length (15,16,17). The limit which the machine can be positioned back from the crest of the digging face depends on the dragline boom length and the fairlead height. As the key gets deeper, the dragline moves forward to position 2 and then position 3 (Figure 2) to keep the drag ropes out of the dirt. Figure 3 shows graphically the amount of material that can be removed from each dragline position.

After the key cut is made, the dragline moves close to the edge of the highwall, position 5 in Figure 4, to remove the remainder of the material. In practice, there may be various intermediate dragline positions on a given cut segment, such as position 4 in Figure 4. After all the remaining material is removed from a given cut segment (digout) from the outside position, the dragline walks back to new working position 1 in Figure 4 and repeats the cycle.

After this brief description of the general procedure of overburden removal for side casting, it is appropriate to discuss the factors affecting the dragline selection.

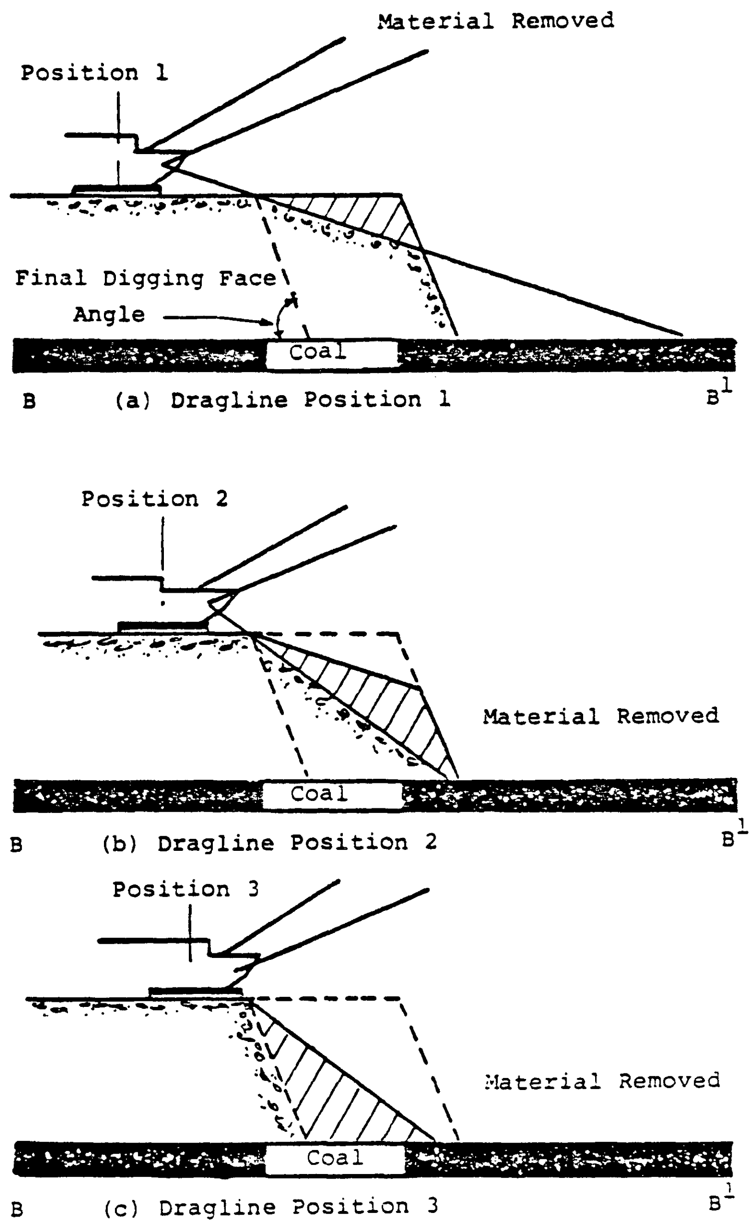


FIGURE 3: Cross Sectional Areas of Material Removed from Each Dragline Position to Make the Key Cut.

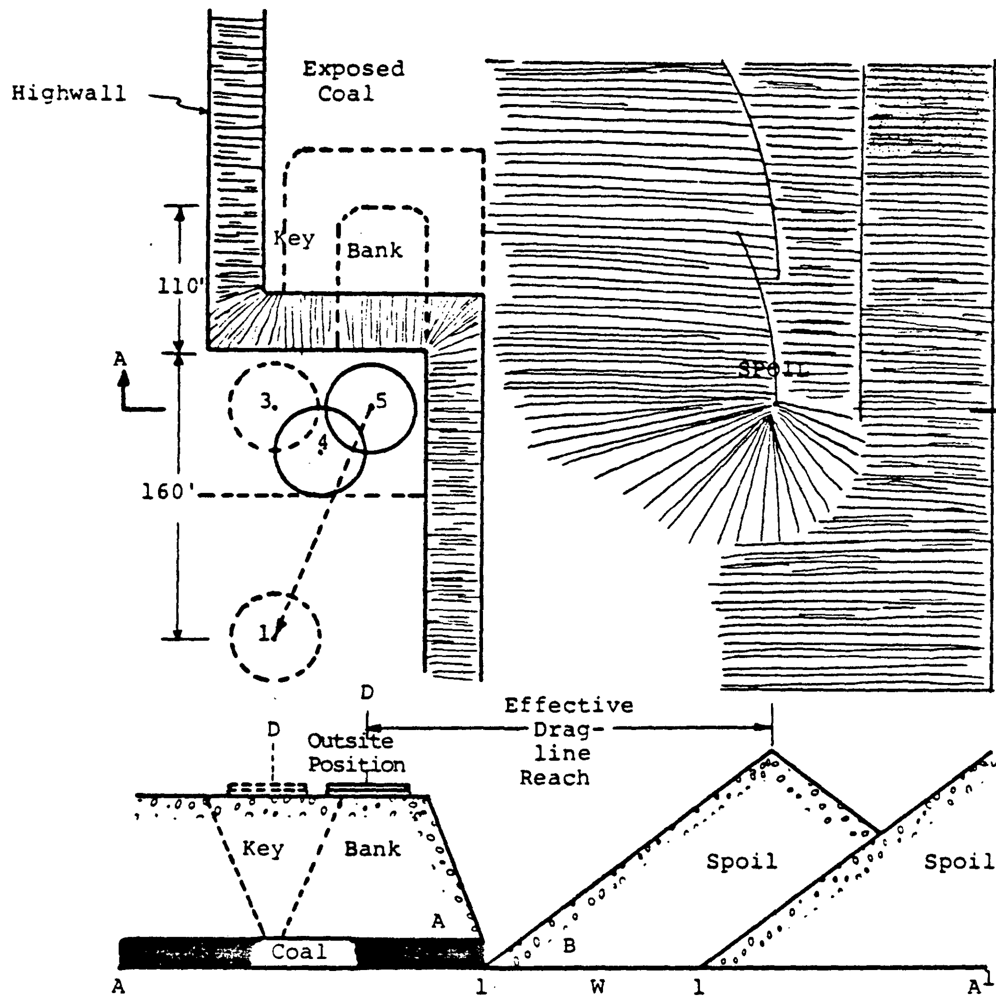


FIGURE 4: Plan and Cross Sectional View of Dragline Positions to Remove Bank Material.

Selection of Dragline for Side Casting

The selection of a dragline is an important consideration for a strip coal mine since it constitutes the largest unit capital outlay and since its operation may account for as much as 60% of the total operating cost in high stripping ratio operations. In Table 1, percentage cost of unit operations for a high strip ratio dragline strip mining operation is shown. Hagood (4) based his dragline selection for side casting upon two factors: 1) Machine ability to spoil the overburden at a sufficient distance from the highwall, and 2) Machine ability to provide adequate productive capacity to meet required rate of production. In this study, a third factor is considered in machine selection; selection of the machine which will provide minimum cost per ton of coal produced.

The primary dragline dimensions required to do the selection are the dragline boom length determined from the required dragline reach and maximum suspended load determined from the required bucket capacity. Knowing the required reach and maximum suspended load, the actual machine is then selected from available models with specifications closely matching the requirements. Each model may also have a number of combinations of boom length, boom angle, and maximum suspended load to suit to the particular operation. A typical specification sheet is shown in Figure 5.

TABLE 1

OPERATING COST AS PERCENTAGE OF TOTAL COST

BY FUNCTIONS IN HIGH RATIO STRIP MINE (1)

Operation	Percentage Cost
Stripping	60.3
Bank Preparation (Including Blasting)	9.6
Coal Preparation	8.3
Hauling	6.4
Coal Loading	4.9
Reclamation	4.5
Supervision and Mine Office	3.9
Engineering and Prospect Drilling	1.7
Roads	0.4
TOTAL	100.0

basic specifications 2570-W

BUCYRUS-ERIE

Walking Dragline

WEIGHTS:

	Boom length, ft.	335
Net weight*, domestic, approx. (with bucket + 74' base) lbs.		11,515,000
Working weight, approx. (with bucket) lbs.		12,515,000
Ballast weight (furnished by purchaser) lbs.		1,000,000

*Add 375,000# for 80' dia. base. (approx.) and reduce ballast 50,000#
Add 90,000 # for blocking on cars when estimating domestic freight.

BASE:

Outside diameter, ft.-in.	74-0	80-0
Bearing area, sq. ft.	4300	5027
Circle rail diameter, ft.-in.	54-0	
Rollers, quantity	100	
average diameter, in.	16	
Swing rack, pitch diameter, ft.-in.	42-8	

WALKING MOUNTING:

Shoe, width and length, ft.	14 x 72	14 x 72
combined bearing area, sq. ft.	2016	2016
Overall width over shoes, ft.-in.	104-6	110-6
Cam diameter, ft.-in.	10-0	
Length of step, approx. ft.-in.	8-6	
Walking speed, approx. m.p.h.	0.15	

REVOLVING FRAME:

Upper machinery frame, width x length, ft. .... 86½ x 99½
Girder depth, upper frame, ft.-in. 12-0

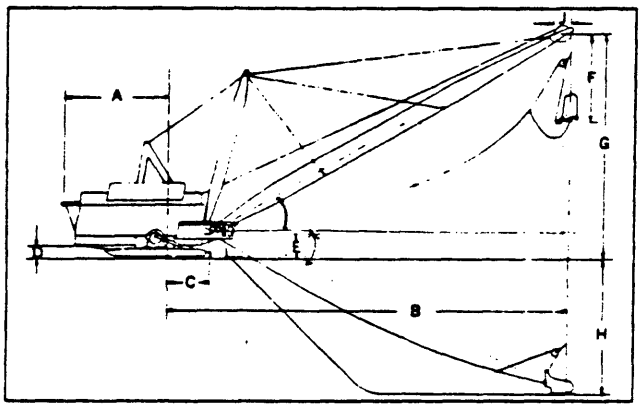
ELECTRICAL EQUIPMENT:

Hoist motors (blown) .... eight 625/1300 h.p.
Drag motors (blown) .... eight 500/1045 h.p.
Swing motors (blown) .... four 625/1300 h.p.
Walking motors (blown) .... four 500/1045 h.p.

All above motors rated at 75° continuous and at 230/475 V.

MG Set Drives: four 3000 h.p. Synch. mtrs. ... 3/60/6900 V.

High Voltage Transformer 15,000 KVA
22,900 V. primary - 6,900 V. secondary



WORKING DIMENSIONS

A Clearance radius, ft.-in. 80-0
B Operating radius .... Read below
C Boom foot radius, ft.-in. 30-0
D Clearance height, ft.-in. 14-0
E Boom foot height, ft.-in 16-0
F Dumping clearance* .... Read below
G Boom point height .... Read below
H Digging depth .... Read below
J Point sheave pitch diameter, in. 144

*Includes allowance for bucket, hoist chains, pick-up link and 10' clearance at hoist sheaves.

NOTE

(1) Rope diameter may change with final geometry.
(2) Ballast requirements may vary pending final stability.
(3) Bucyrus-Erie Company reserves the right to make changes in specifications or design which in its opinion are an improvement or are necessary because of unavailability of materials, without incurring any liability to make such changes on machines previously built.

Boom Length	B Operating Radius	Boom Angle	Maximum Suspended Load (lbs.)	G Boom Pt. Height	G - F Approximate Dumping Height	H Digging Depths	Drag			Hoist		
							Drum Diam.	Rope		Drum Diam.	Rope	
								No.	Diam.		No.	Diam.
335'	326'	30°	520,000	184'	103½'	170'	110"	2	4½"	110"	2	4½"
	310'	35°	550,000	208'	131'	160'	110"	2	4½"	110"	2	4½"
	300'	38°	585,000	222'	139½'	150'	110"	2	4¾"	110"	2	4¾"

Figure 5: A TYPICAL SPECIFICATION SHEET

.After (1)

Required dragline reach depends upon the physical conditions; such as, overburden depth, swell factor, high-wall angle, angle of repose of the spoil pile, and in some cases the thickness of the coal as well as design variables such as pit width, the manner in which material is spoiled, and the machine positioning due to high-wall stability. A mathematical relationship between dragline reach and the physical parameters can be derived from a cut-spoil diagram relationship (Figure 6).

Various authors (4,13,14) derived dragline reach equations in terms of physical and design parameters mentioned earlier.

The classical equation for dragline reach is given below:

$$EDR = H/TAN(A) + H(1+S)/TAN\ (B) + W/4$$

Where:

EDR = Effective dragline reach

H = Overburden depth, ft.

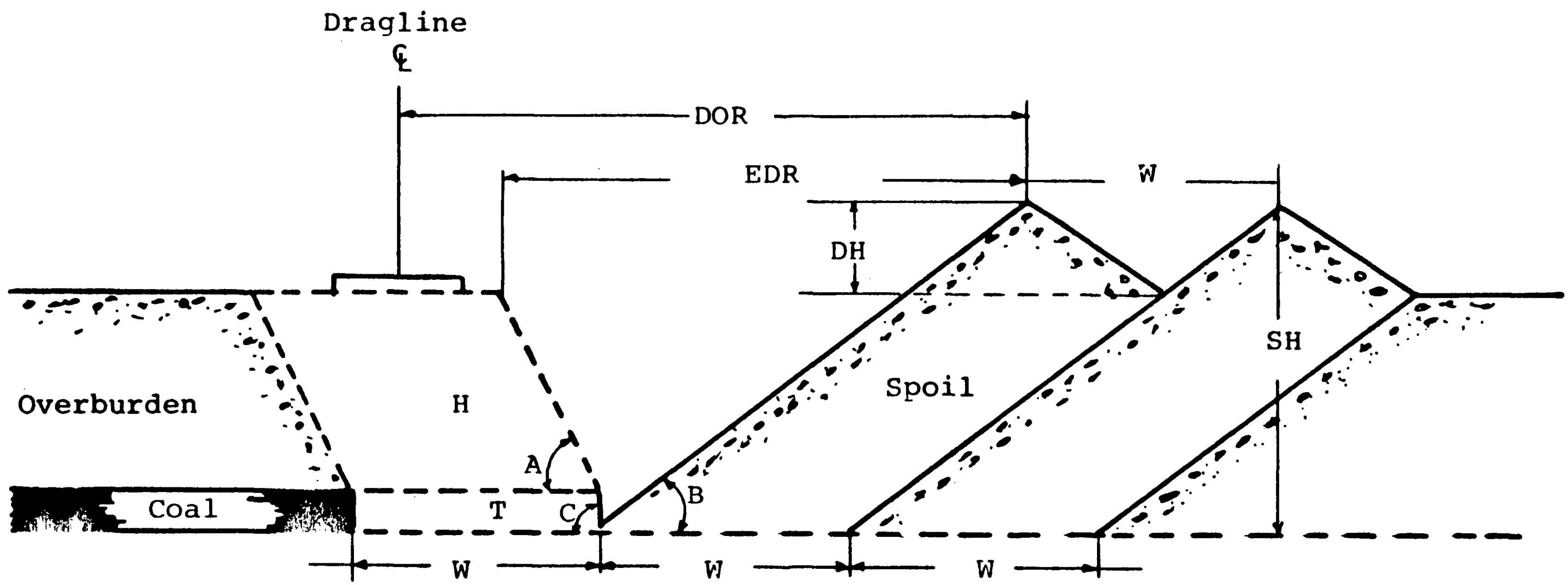
A = Angle of repose for high-wall, degrees

B = Angle of repose for spoil

S = Swell of the material %/100

W = Pit width

This equation is obtained from the mathematical relationship for a cut-spoil diagram (Figure 6) by equalizing the area of the bank adjusted for swell of the material to the area of the spoil.



DOR: Dragline Operating Radius
EDR: Effective Dragline Reach
SH: Spoil Height
W: Pit Width
DH: Dump Height
H: Overburden Height
T: Coal Thickness
A: Highwall Angle of Repose
B: Spoil Angle of Purpose
C: Coal Face Angle
DH: Dumping Height

FIGURE 6: Cut-Spoil Diagram for a Dragline Operation.

Determination of Dragline Reach

P.K. Chatterjee et al (6) stated that this approach is inherently erroneous because cut-spoil diagrams do not consider the fashion in which actual stripping and spoiling is done. Therefore, a new dragline reach equation should be derived considering the total volume of the overburden removed from each position and the volume of the necessary spoil room to store this material without creating rehandle.

For the purpose of this study, effective dragline reach (EDR) is defined as the horizontal distance from the highwall crest to the spoil pile peak; that is, the dragline operating radius (DOR) minus one-half the tub diameter, minus a safety margin left at the edge of the highwall. This safety margin is the distance between the edge of the tub and the highwall crest. One-half the tub diameter plus the safety margin left at the edge is referred to as positioning distance (P). Dragline operating radius (DOR) is defined as the horizontal distance from the center of machine rotation to the spoil peak under the boom point. Effective dragline reach gradually increases to its maximum when the swing angle approaches 90 degrees. Effective dragline reach, tub diameter, positioning, and dragline operating radius are shown in Figure 1.

Three Dimensional Approach

Dragline positioning and the manner in which material is spoiled affects the required dragline operating radius. In Figure 7, the dragline is positioned a predetermined distance away from the digging face and a safety margin away from the high-wall crest and starts removing overburden and spoiling it such that the smallest swing angle can be obtained without necessitating rehandling. It is assumed that key cut material has already been removed and the machine has moved to the outside position (Figure 7).

The dragline spoils the material along the curvature of the radius starting from the last spoiling point from the previous position. Figure 7a shows previous dragline spoil point which is labeled as position 1. The length of the spoil area should be the same as the length of the cut from which material is removed. Position 2 in Figure 7a corresponds to the end of spoil pile to be utilized for removal of the cut. If one takes cross sections, one going through position 1 and the other going through position 2, as shown in Figure 7b and 7c, it can be seen that effective dragline reach corresponding to position 1 is smaller than the one corresponding to position 2. Since the effective dragline reach dictates the amount of material to be spoiled, the volume spoiled at position 1 will be less than the volume spoiled at position 2.

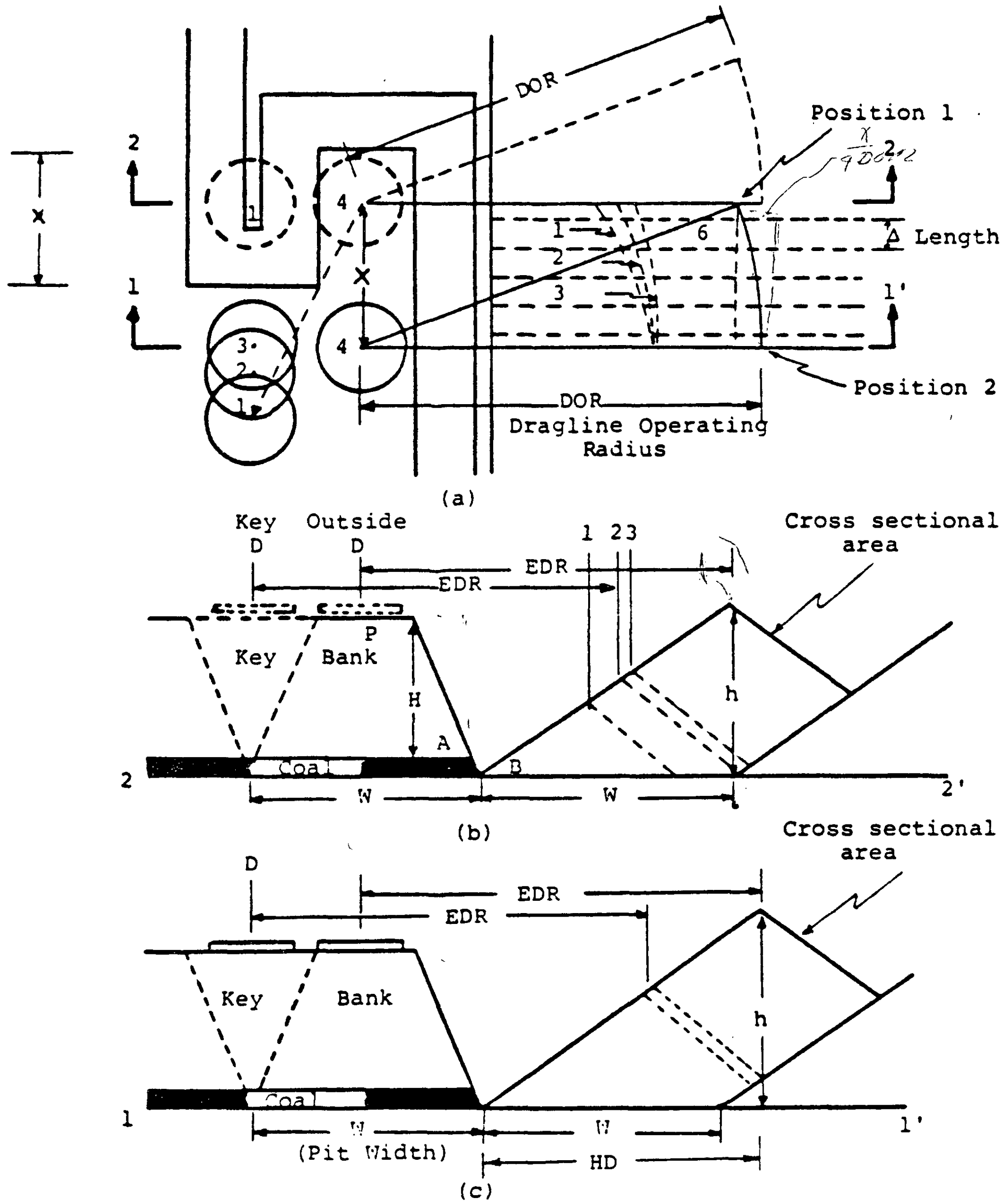


FIGURE 7: Plan and Cross Sections of Dragline Positions, Spoil Location and Required Dragline Spoil Radius.

The dragline reach calculated from the classical equation 1, assumes the dragline always dumps the spoil of a 90^{o} swing to position 2 in Figure 7a, rather than along the curvature. Because of this assumption, actual volume of the available spoil room is overestimated. Therefore, the value of the required dragline reach obtained from this equation is erroneous. Considering this fact, dragline reach can be calculated such that volume of the spoil room made available from a given dragline position is equal to the volume of the material to be removed with adjustment for swell.

An expression for the total volume of the spoil room along the cut segment (from position 1 to position 2 on Figure 7a) can be derived by taking unit volume and integrating this unit volume for the entire length of the spoil cut segment.

$$\text{Unit volume} = \text{Cross Sectional Area} \times \Delta\,\text{Length} \quad \text{----------} \quad (1)$$

The cross sectional area of the spoil changes (from position 1 to position 2 in Figure 7a) along the curvature of the dumping radius: it becomes necessary to express the cross-sectional spoil area in terms of radius of curvature.

$$CSA = W \times h - \frac{W^2}{4} \times \mathrm{TAN}\ B \quad \text{--------------------------} \quad (2)$$

Where:

CSA = Cross Sectional Area

W = Pit Width

h = Spoil Height

B = Angle of Repose for Spoil

From Figure 7b, 7c:

$$h = HD \times TanB \quad \text{----------------------------------} \quad (3)$$

and

$$HD = (DOR^2 - X^2)^{\frac{1}{2}} - P - \frac{H}{Tan\,A} - \frac{T}{TanC} \quad \text{---------} \quad (4)$$

Where:

HD = Horizontal distance from the toe of the coal to the spoil point

DOR = Dragline operating radius

X = Cut segment length (also spoil length)

P = Distance from the center of dragline to crest of the high-wall

H = Overburden height

A = High-wall angle

T = Coal thickness

C = Coal face angle

Substituting equation (4) into equation (3)

$$h = ((DOR^2 - X^2)^{\frac{1}{2}} - P - \frac{H}{TanA} - \frac{T}{TanC}) \times Tan\ B \quad \text{----} (5)$$

Substitute equation (5) into equation (2)

$$CSA = W\ ((DOR^2 - X^2)^{\frac{1}{2}} - P - \frac{H}{TanA} - \frac{T}{TanC})Tan\ B - \frac{W^2}{4}\ Tan\ B \quad \text{---} (6)$$

Rearranging equation (6)

$$CSA = W \text{ Tan } B \; ((DOR^2 - X^2)^{\frac{1}{2}} - P - \frac{H}{TanA} - \frac{T}{TanC} - \frac{W}{4}) \text{ --(6a)}$$

Substitute equation (6a) into equation (1)

$$\text{Unit volume} = W \text{ Tan } B \; ((DOR^2 - X^2)^{\frac{1}{2}} - P - \frac{T}{TanC} - \frac{W}{4}) \cdot \Delta X \text{ ---(7)}$$

Integrating equation (7) for a given cut length (limits 0 to X)

$$\text{Spoil volume} = W \text{ Tan } B \; (\tfrac{1}{2} DOR^2 \sin^{-1} \frac{X}{DOR} + \tfrac{1}{2} X \; (DOR^2 - X^2)^{\frac{1}{2}} - P \cdot X$$

$$- \frac{H \cdot X}{TanA} - \frac{T \cdot X}{TanC} - \frac{W \cdot X}{4}) \text{ -------------------------(8)}$$

Since for small angles:

$$\text{Arc Sin } \frac{X}{DOR} = \frac{X}{DOR}$$

$$V = W \text{ Tan } B \; (\tfrac{1}{2} DOR^2 \times \frac{X}{DOR} + \tfrac{1}{2} \cdot X \cdot (DOR^2 - X^2)^{\frac{1}{2}} -$$

$$P \cdot X - \frac{H \cdot X}{TanA} - \frac{T \cdot X}{TanC} - \frac{W \cdot X}{4})$$

$$V = W \cdot X \cdot \text{Tan } B \; (\frac{DOR + (DOR^2 - X^2)^{\frac{1}{2}}}{2} - P - \frac{H}{TanA} - \frac{T}{TanC} - \frac{W}{4}) \text{- (9)}$$

V = Volume of the spoil space

Since volume of the spoil has to be equal to volume of the material removed adjusted for swell,

$$X \cdot W \cdot H \cdot (1+S) = W \cdot X \cdot \text{Tan } B \; (\frac{DOR + (DOR^2 - X^2)^{\frac{1}{2}}}{2} - P -$$

$$\frac{H}{TanA} - \frac{T}{TanC} - \frac{W}{4})$$

By rearranging the terms:

$$DOR = \frac{H}{TanA} + \frac{T}{TanC} + \frac{H(1+S)}{TanB} + \frac{W}{4} + P + \frac{X^2}{4\left(\frac{H}{TanA} + \frac{T}{TanC} + \frac{H(1+S)}{TanB} + \frac{W}{4} + P\right)} \quad \text{------------------ (10)}$$

$$\text{If } ODOR = \frac{H}{TanA} + \frac{T}{TanC} + \frac{H(1+S)}{TanB} + \frac{W}{4} + P$$

Where ODOR : Old Dragline Operating Radius

$$DOR = ODOR + \frac{X^2}{4\cdot(ODOR)}$$

When swing angle is 90°, which is when $X = 0$, equation (10) becomes:

$$ODOR = DOR = \frac{H}{TanA} + \frac{T}{TanC} + \frac{H(1+S)}{TanB} + \frac{W}{4} + P$$ which is the classical equation.

This new dragline equation takes effective dragline reach at the first point and effective dragline reach at the last point of spoiling and then averages these two to arrive at the dragline spoil radius.

To illustrate the use of this equation, consider an example where:

H: Overburden depth = 100'

W: Pit width = 100'

S: Swell of the material = 25%

A: Highwall angle = 63.4°

B: Spoil angle = 38.5^{o}

T: Coal thickness = 20'

C: Coal angle = 90^{o}

X: Cut length = 100'

P: Dragline position = 50'

$$DOR = \frac{H}{TanA} + \frac{T}{TanC} + \frac{H(1+S)}{TanB} + \frac{W}{4} + P + \frac{X^2}{4\left(\frac{H}{TanA} + \frac{T}{TanC} + \frac{H(1+S)}{TanB} + \frac{W}{4} + P\right)}$$

$$ODOR = \frac{H}{TanA} + \frac{T}{TanC} + \frac{H(1+S)}{TanB} + \frac{W}{4} + P$$

ODOR = 282'

$$DOR = 282 + \frac{(100)^2}{(4)\ (282)} = 291'$$

The dragline spoil radius from this new equation is 291' whereas from the classical equation it would have estimated to be 282'.

Volume of spoil room available from this dragline spoil radius for the cut segment of X = 100'

$$\text{Spoil Volume} = W.X.\ Tan\ B\left(\frac{DOR+(DOR^2-X^2)^{\frac{1}{2}}}{2} - P - \frac{H}{TanA} - \frac{T}{TanC} - \frac{W}{4}\right)$$

Spoil Volume = 1,249,000 ft^3

Volume required to be removed = W·H.X (1+S) = 1,250,000 ft^3

With the given dragline reach, all of the material can be spoiled without any rehandle.

Bucket Capacity

For selection of a dragline, determination of the bucket capacity to provide the required yardage removal capability is the second step after the required dragline spoiling radius is obtained. Required bucket capacity is primarily dependent on the rate at which overburden must be stripped. Proposed yearly coal production explicity determines the rate at which overburden must be stripped.

The general equation for annual dragline production is given below:

$$\underset{(Yd^3)}{\text{Annual Production}} = \left(\text{Bucket Capacity}\right)\left(\text{Fill Factor}\right)\left(\frac{1}{\underset{(\%)}{1+\text{Swell Factor}}}\right)\left(\frac{\text{Scheduled Hours}}{\text{Year}}\right)$$

$$\left(\text{Mechanical Availability}\right)\left(\text{Job Factor}\right)\left(\frac{3600}{\underset{(Sec)}{\text{Cycle Time}}}\right)$$

This equation states that annual machine production should be the amount of material that can be put into the bucket times number of buckets that are filled and dumped in an hour. Annual production is the product of hourly production times number of hours the machine is actually removing overburden. The actual removing time or digging time is also the product of machine availability times the job efficiency factor.

Dragline scheduled hours is the time period in terms of hours that the dragline is scheduled to work. The scheduled hours make allowance for holidays, miner's vacation, weather related idle time, other idle time, and in some cases scheduled maintenance.

The dragline mechanical availability is the factor to make allowance from the scheduled hours for periods of time that machine is not operating due to scheduled, unpredicted mechanical and electrical failures. Failure of mechanical systems such as tub, drag, hoist, and swing motors, ropes, boom, and bucket are some of the elements of mechanical delays.

Periods of time in which a dragline is mechanically available but, it is not doing productive work are referred to as job related delays and are accounted for in the job efficiency factor. Idle time, supervision, supply and lunch, shooting, power failures, moving power cable, dozing, deadheading, oiling are all elements of job related delays.

Bucket fill factor is the adjustment made to the rated capacity of the bucket to account for the actual volume of material in the bucket for each pass. This volume of the material is dependent on the material qualities, digging face angle and on the operator's ability to completely fill the bucket. Dragline manufacturers suggest that bucket fill factor values are in the 80 to 95 percent range, although it is possible to have a fill factor greater than 100 percent.

Swell factor is another adjustment made for the increase in volume of the material when displaced from the bank to deposition on the spoil pile. Since material loaded into the bucket increases in volume, the swell factor makes the necessary adjustment to express volume of the material spoiled in terms of equivalent in situ bank cubic yard. Table 2 shows approximate swell factor for various overburden materials.

Cycle time is the length of time it takes to fill, hoist and swing over, dump the bucket and return for the next. The elements in dragline's cycle time can be listed as follows:

1. Dig (load the bucket)
2. Hoist and swing over
3. Dump and swing back
4. Positioning

The skill of the operator has a large effect on the amount of time required for a cycle time. Assuming that the operator has reasonable skill, discussion of the other factors affecting the cycle time follows.

Digging time depends primarily upon how well the overburden is fragmented as well as the digging face angle. The method of blasting dictates directly the digging conditions.

Hoist and swing time of the dragline is controlled by horsepower limitations of the machine (8,12) and the angle through which the dragline swings to spoil the material.

TABLE 2

TYPICAL MATERIAL SPECIFIC GRAVITIES AND SWELL FACTOR. AFTER (4).

Material	Specific Gravity	In Situ Weight Lbs.	Approximate Swell Factor	Swelled Weight (Lbs.)
Breccia	2.41	4050	27	3190
Clay (Dry)	1.91	3220	20	2680
Clay (Damp)	1.99	3350	20	2790
Conglomerate	2.21	3720	33	2800
Diorite	3.10	5220	33	3430
Gneiss	2.71	4550	33	3480
Granite	2.69	4540	33	3410
Limestone	2.61	4380	36	3220
Sandstone	2.42	4070	34	3030
Shale	2.64	4450	33	3350
Slate	2.68	4500	33	3380

Overburden depth, pit width, dragline set up positions for a given cut, and the manner of spoiling, all affect the necessary swing angle to be made to spoil the material away from the coal. Knowing the dragline location and the manner in which spoiling is done, the average swing angle for a particular operation can easily be found by either using a calculator or a computer.

Determination of the average swing angle by a computer is discussed further in model development.

For each dragline, a swing time vs. swing angle curve can be obtained. It is suggested that all machines are designed to cycle in approximately the same time. Therefore, one swing time vs. swing angle curve could be used for general cases. Table 3 lists various B-E machines and their approximate average cycle times for 120 degree swing angle and shows some differences on the order of 2 to 4 seconds as the boom length increases. Swing time curves in Figure 8 and 9 for a specific machine reflect boom length, horsepower, etc. Time to load a bucket can be, on average, assumed constant and positioning the bucket usually takes 3 seconds and dumping 3 seconds (15). Knowing the swing, load, dump, position time, and average delay time, total cycle time can be obtained for a given swing angle.

If the annual overburden requirement is given and the bucket capacity is to be determined, numerical values for known parameters can be substituted into annual production equations and required bucket capacity can be calculated.

TABLE 3

WALKING DRAGLINES

MODEL NUMBER	BOOM LENGTH FT.	BUCKET CAPACITY CU YDS LIGHT	MEDIUM	HEAVY	APPROX. AVG. CYCLE TIME, SEC
180-W	120	6	6	5	45
180-W	135	5	5	4.5	46
480-W	175	18	17	17	56
480-W	195	16	15	14.5	58
480-W	215	13.5	13	12.5	59
500-W	175	16	15.5	15	56
500-W	195	14	13.5	13	57
770-B	195	22	21	20	58
770-B	215	20	19	18.5	59
800-W	195	26	25	24	57
800-W	220	23	22	21	58
800-W	245	19	18.5	18	59
1260-W	235	36	35	34	57
1260-W	260	30	29	28	58
1260-W	285	25	24	23	59
1350-W	235	53	51	49	57
1350-W	260	49	47	45	58
1350-W	285	42	40	39	59
1450-W	250 ±	65	62	60	57

(Continued)

TABLE 3

WALKING DRAGLINES

(Continued)

MODEL NUMBER	BOOM LENGTH FT.	BUCKET CAPACITY CU YDS LIGHT	MEDIUM	HEAVY	APPROX. AVG. CYCLE TIME, SEC
1550-W	250	67	65	63	57
1550-W	275	58	56	54	58
1550-W	300	48	46	45	59
2550-W	275	80	77	75	58
2550-W	300	74	72	70	60
2650-W	275	130	125	120	49

* All booms at 30 degrees unless otherwise indicated.
ǂ Boom at 38 degrees.
‡ Assume approx. 120° average swing angle and average digging.

(Information provided by Bucyrus-Erie)

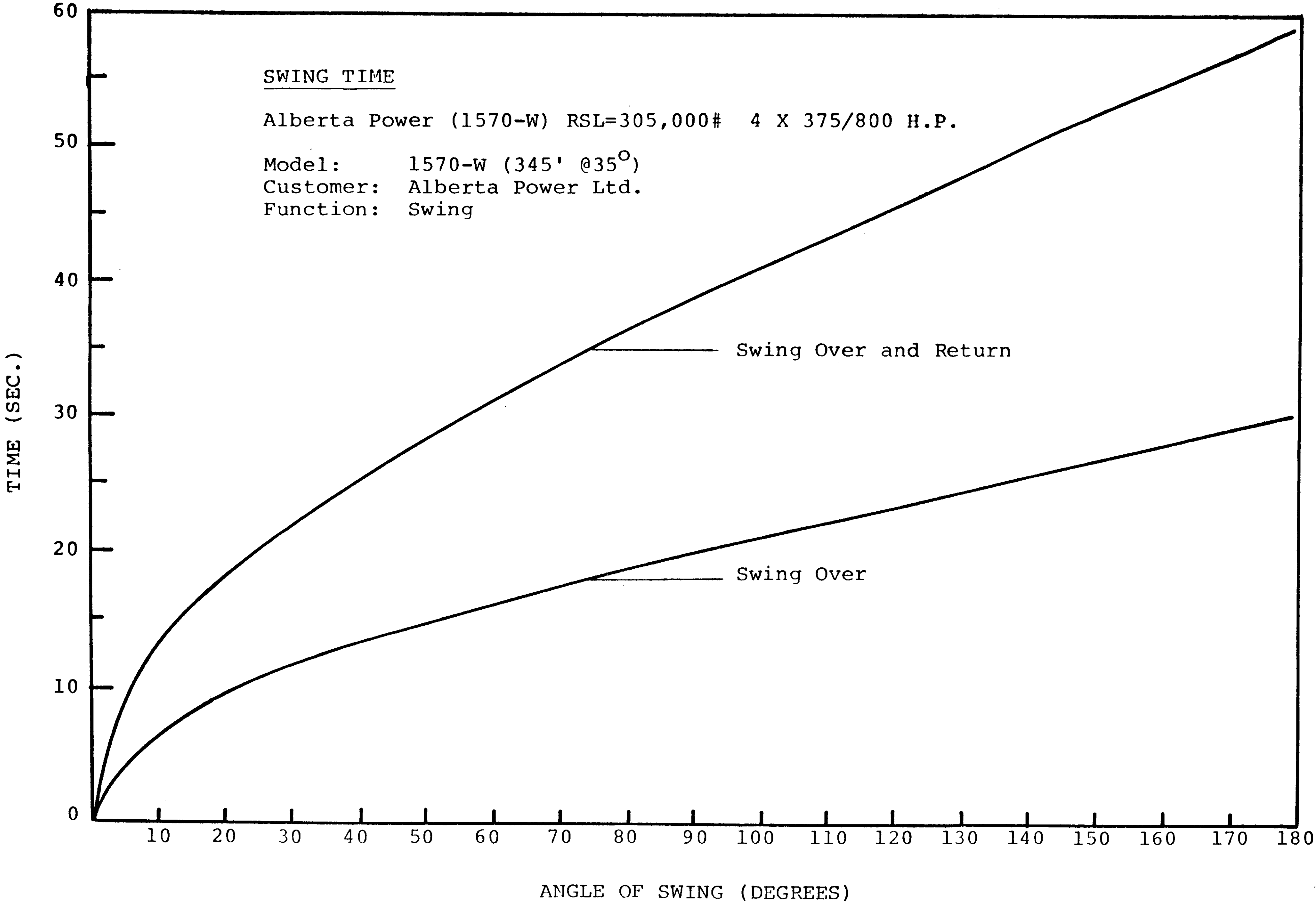


Figure 8 : Swing Angle vs. Swing Time Curve for the Bucyrus-Erie Model 1570 Machine

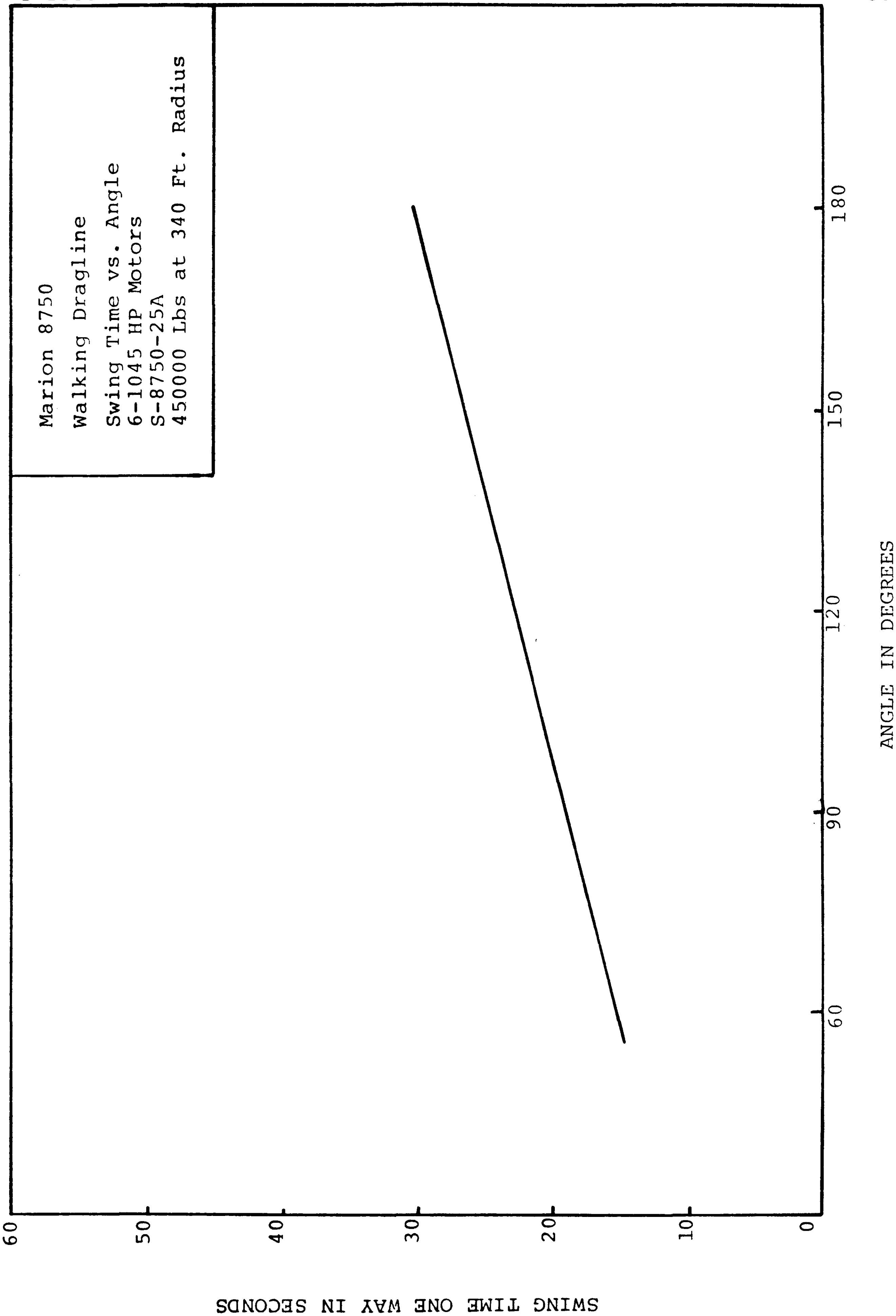


Figure 9 : Swing Angle vs. Swing Time for the Marion 8750 Machine

Suspended Load Determination

Dragline manufacturers give suspended load as the selection parameter for machine size. Calculated bucket capacity is converted into suspended load by combining weight of the bucket and weight of the material in the bucket. The average weight of the bucket itself is expressed in terms of pounds per cubic yard of bucket capacity. The information can be represented graphically (Figure 10). These weights represent medium duty buckets, typically used in coal stripping operations.

Weight of the material also varies with overburden type as shown in Table 2.

Once the required dragline reach and suspended load is determined, the dragline selection is made by going through various existing model specifications of different manufacturers. A machine with specifications closely matching the required reach and the suspended load is then selected as the candidate dragline for the property.

Operating and Owning Cost Determination

Once the dragline size is determined, owning and operating cost for the machine can be determined to estimate cost of overburden removal per ton of coal.

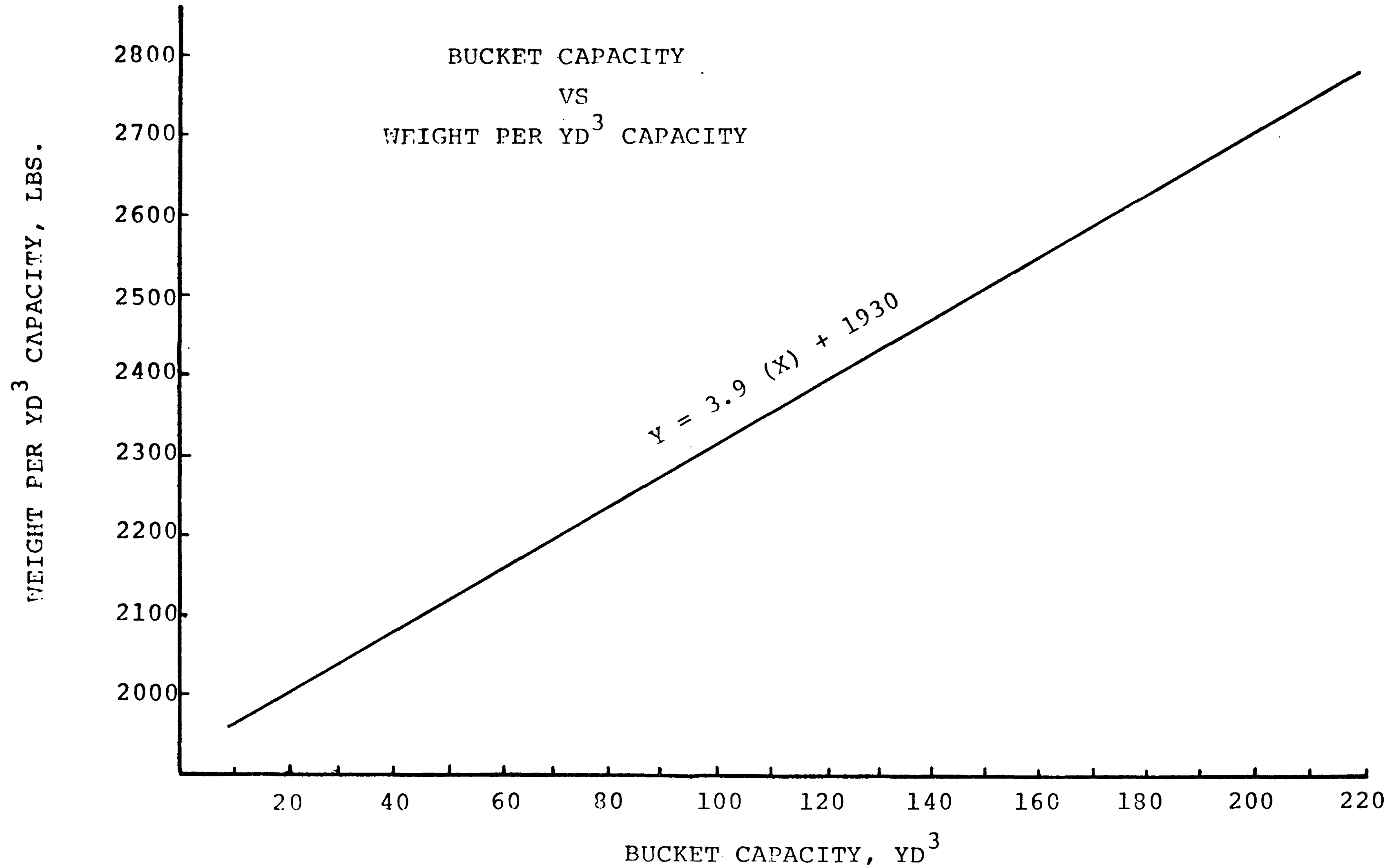


Figure 10. Dragline Bucket Capacity vs. Weight Per Yd^3 Capacity For Medium Weight Buckets (After Hagood)

Ownership cost for a machine traditionally consists of depreciation, and interest, taxes and insurance cost. Dragline depreciation cost is usually calculated using the straight line method of depreciation and life of the dragline is usually considered to be from 15 years to 30 years. Total dragline investment cost includes purchase price for the machine plus freight, trail cable, ballast and erection costs. Interest, taxes and insurance cost is often calculated as percentage of average annual investment. The following equation determines the average investment:

$$\text{Average investment} = \text{Original investment} \times \frac{N+1}{2N}$$

$$\text{Interest, taxes, insurance cost} = \text{Average investment} \times \text{Percent I,I,T}$$

Operating cost consists of power, repairs, maintenance and supplies, and the labor costs. The number of people assigned will be a function of the machine size and labor contract.

Cost of power is dependent on the power consumption for a given machine and the cost per KWH. Power consumption can either be calculated as a function of machine horsepower or from emperical data provided by machine manufacturers (Figure 11).

The cost of maintenance, repairs, and supplies is the most difficult cost item to estimate because it is influenced by many variables. Hagood (4) calculated R.M.S. cost as a function

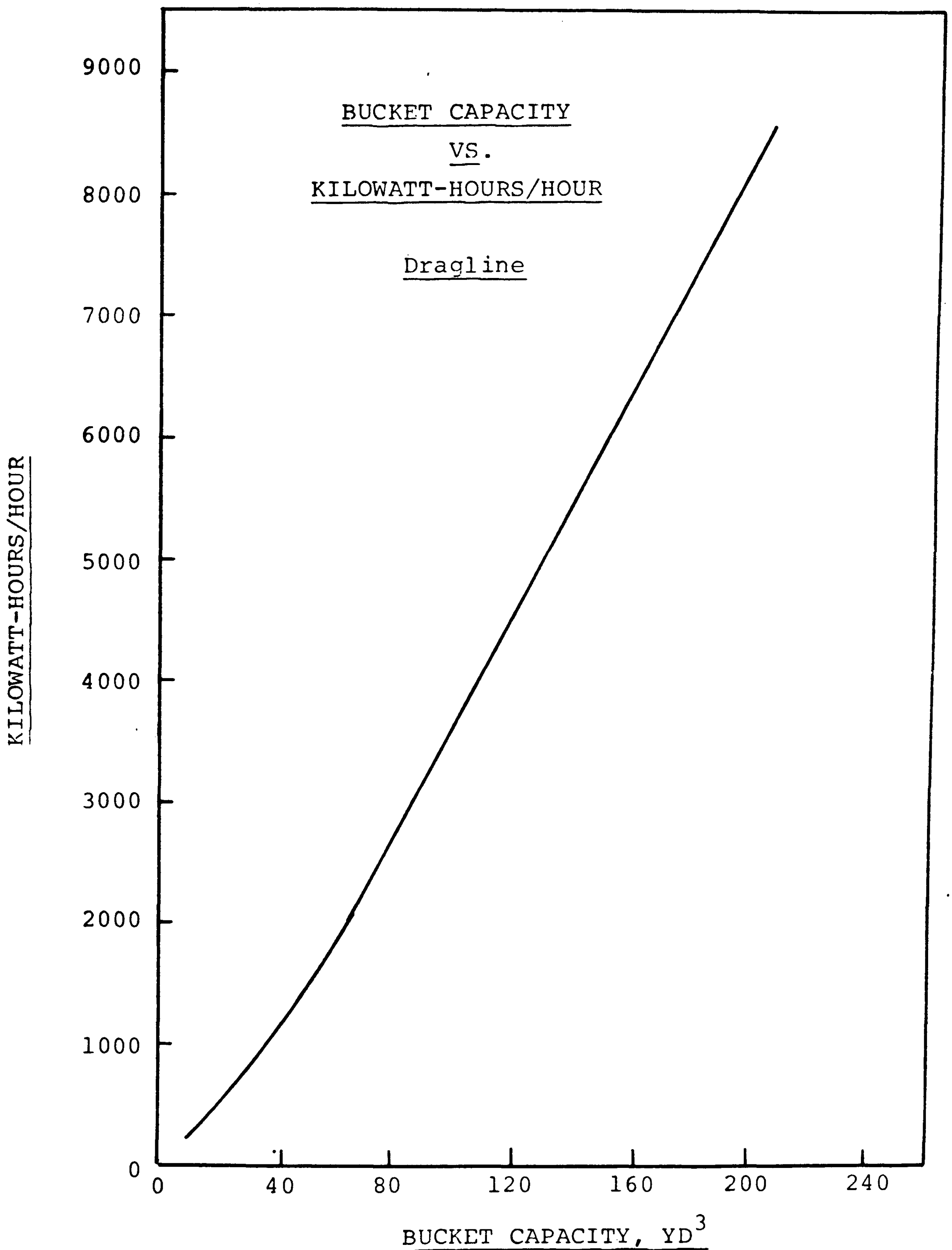


Figure 11: Bucket Capacity vs. Kilowatt-Hours/Hour. (After Hagood)

of the power cost, based on the assumption that the cost of repairs, parts and labor are related to electrical power cost. This relationship follows:

$$Y = \frac{1}{0.004\ (X) + 0.2982}$$

Y: The ratio of maintenance cost to power cost

X: Bucket capacity, YD^3

This relationship is shown in Figure 12. Information provided by B-E in 1978, suggested an average R.M.S. cost of 6¢/bank yard moved.

Labor cost per hour is a function of local labor rates and union affiliation.

Draglines are often required to operate in high overburden and other conditions which require use of methods other than side casting. When this is the case, other stripping methods such as chop down, extended bench or pull back methods might be employed. In the following pages, these methods are discussed.

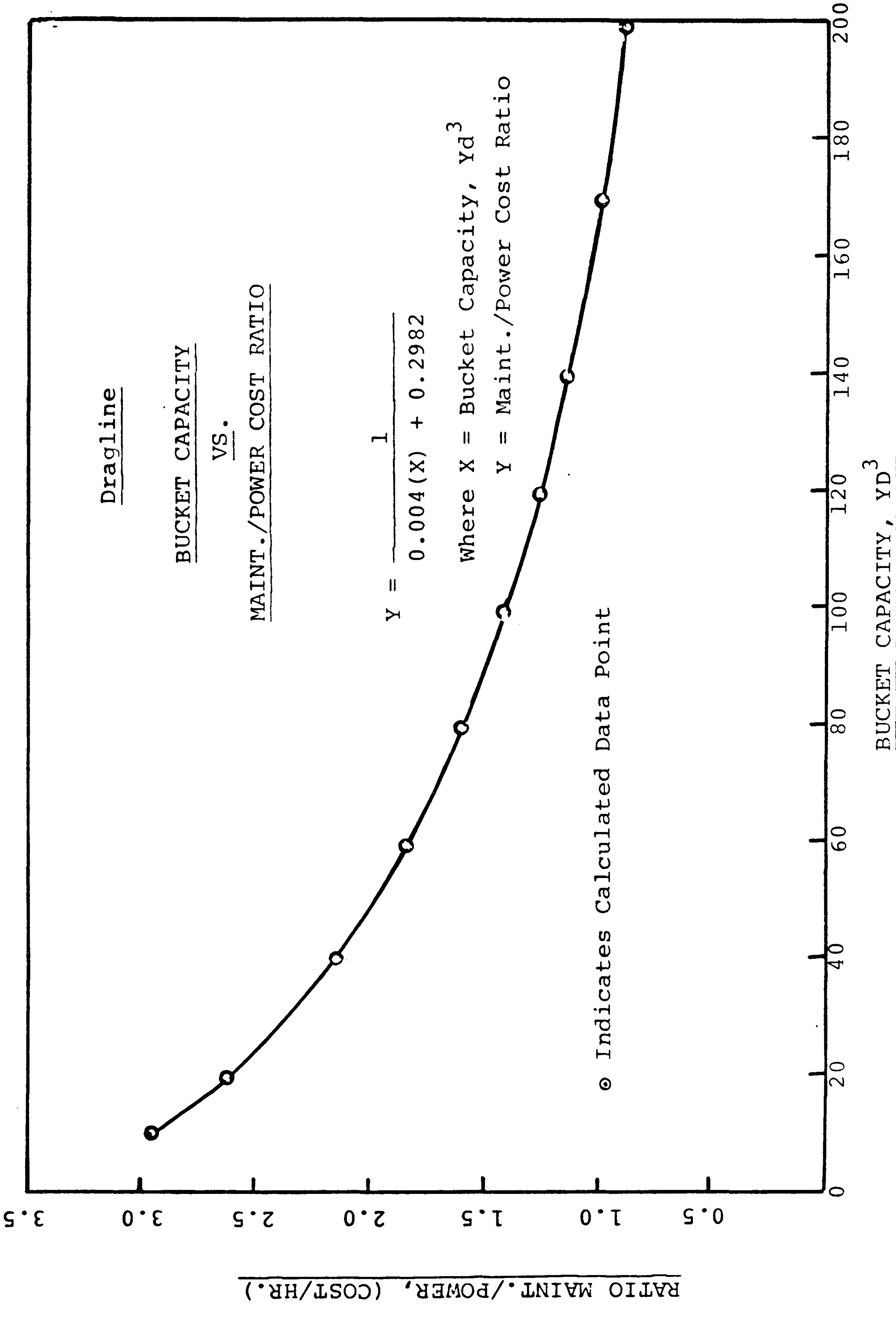


Figure 12: Bucket Capacity Vs. Maint./Power Cost Ratio
(After Hagood)

CHOP DOWN METHOD

General Description of the Method

Chop down stripping is a method where a portion of the overburden above the elevation of the dragline operating bench is chopped by the dragline before or after the remaining overburden can be removed by side casting or with extended bench.

The dragline works at an elevation lower than the original ground surface and chops down portions of the overburden as seen in Figures 13 and 14.

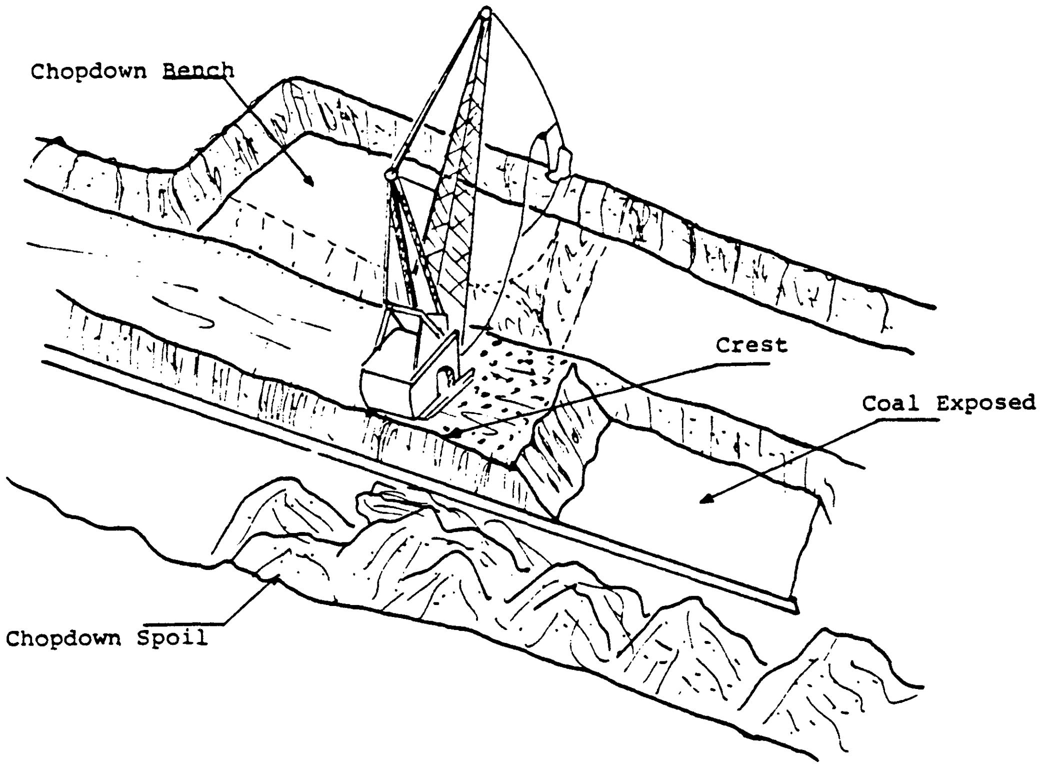
Application of chop down procedures can vary from operation to operation. According to the Bucyrus-Erie study, most common applications are:

a) Dragline working pad preparation

b) Selective overburden removal

c) Extending effective dragline reach

The chop down method is commonly used to prepare a leveled dragline working bench, where terrain is hilly and frequent ridges exist or when surface conditions are soft and unsuitable for machine support. The procedure described in the Bucyrus-Erie study suggests that the dragline starts working at the lower elevation bench and prepares a stable, leveled working bench for itself by either chopping directly behind or from the next pit over. Figure 15 shows this procedure in plan and cross section.



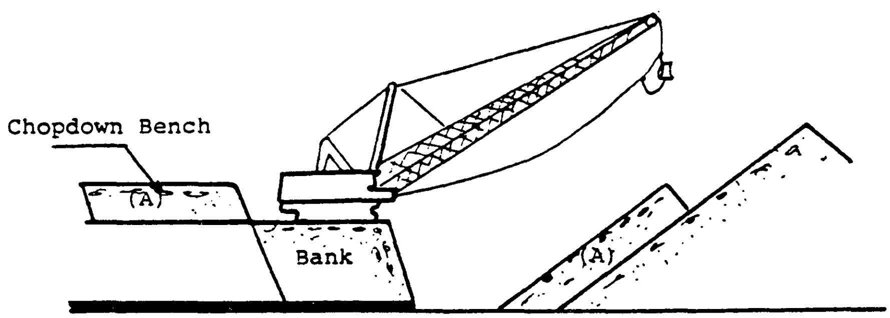


Figure 13: Artist Conception and Cross Sectional View of Chop Down Operation.

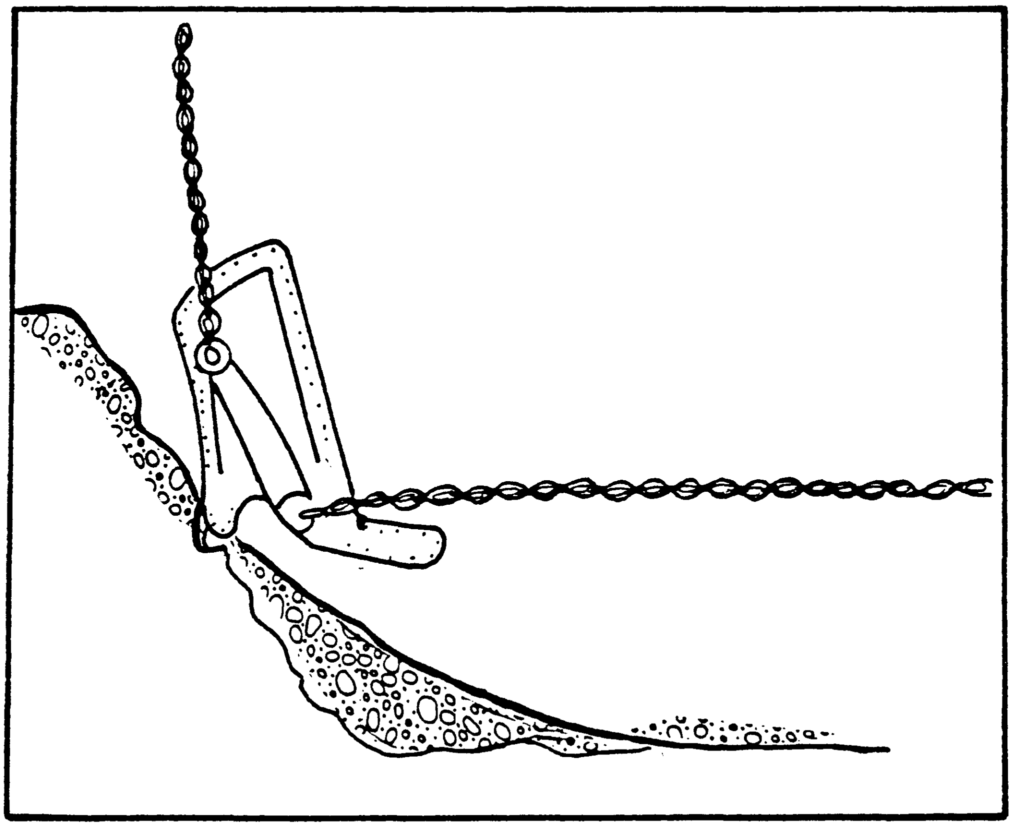


Figure 14: Position of Bucket Relative To Bench For Chop Down Procedure.

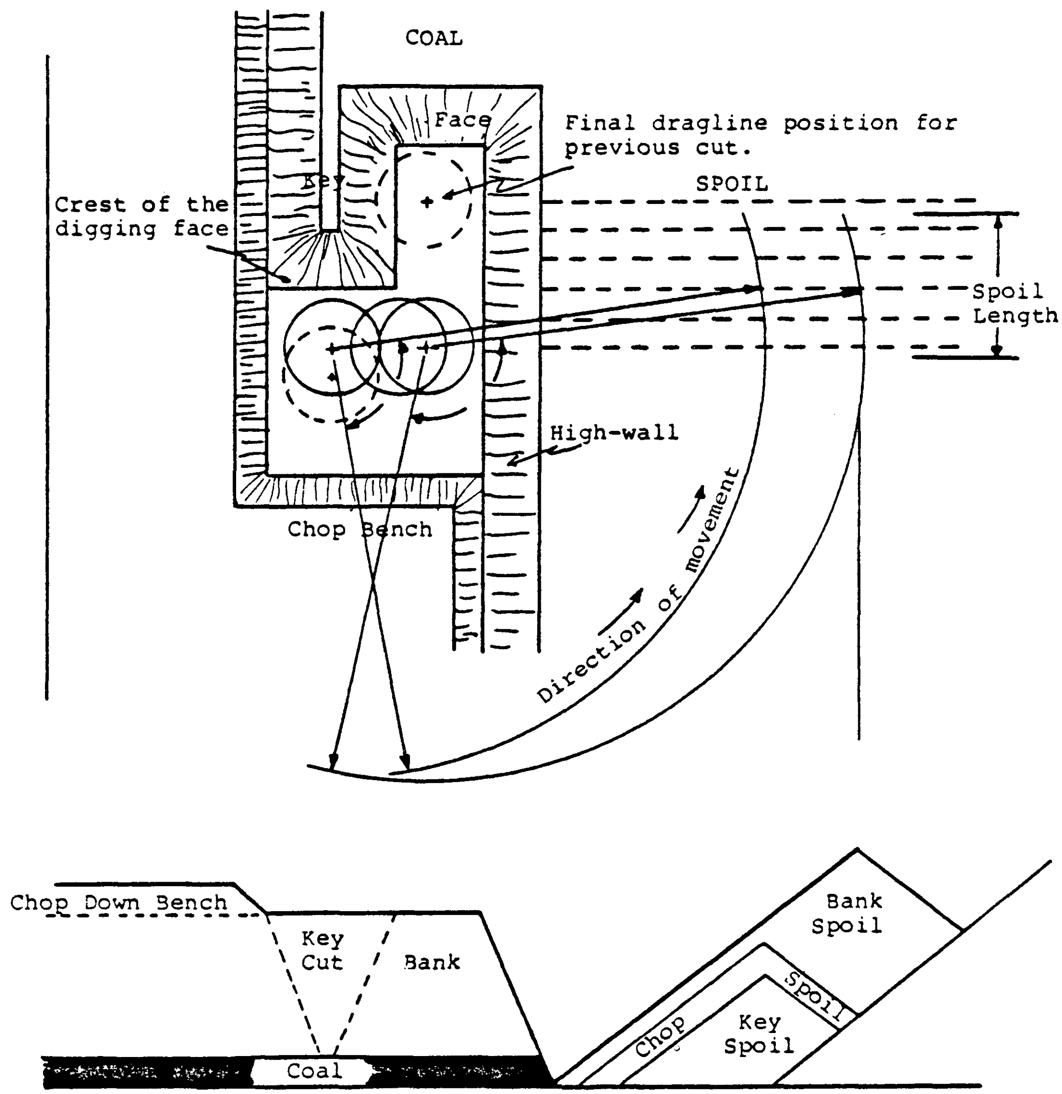


Figure 15: Plan and Cross Sectional View of Dragline Positions for Back Chopping to Prepare a Working Pad.

Selective overburden removal is necessary for stripping operations where toxic overburden strata lying immediately above the coal bed is encountered. When the previously discussed side casting method is used to remove overburden, this toxic material covers the top portion of the spoil piles. This causes subsequent reclamation and water problems. The chop down method becomes viable for burial of this strata. As shown in Figure 16, the procedure is such that dragline removes the overburden material A and B by conventional side casting, then from the same position the dragline also reaches overhand and chops down the bench C from the adjacent pit and places this overburden at the top of spoil A and B burying the toxic material.

Application of the chop down method can reduce and in some cases, may eliminate rehandle in stripping operations where dragline reach is not quite sufficient to spoil the overburden. Effective spoil radius of a machine can be increased because of the effect of the highwall angle by lowering dragline working level as shown in Figure 17. As the depth of the chop down bench increases, the amount rehandled will decrease. The percent rehandle decrease will be proportional to the additional spoil room gained by the chop down operation. The mathematical relationship between the chop down bench height and spoil room gained per unit bench height will be discussed later in the section on selection of dragline for chop down method.

While the chop down method provides operating flexibility,

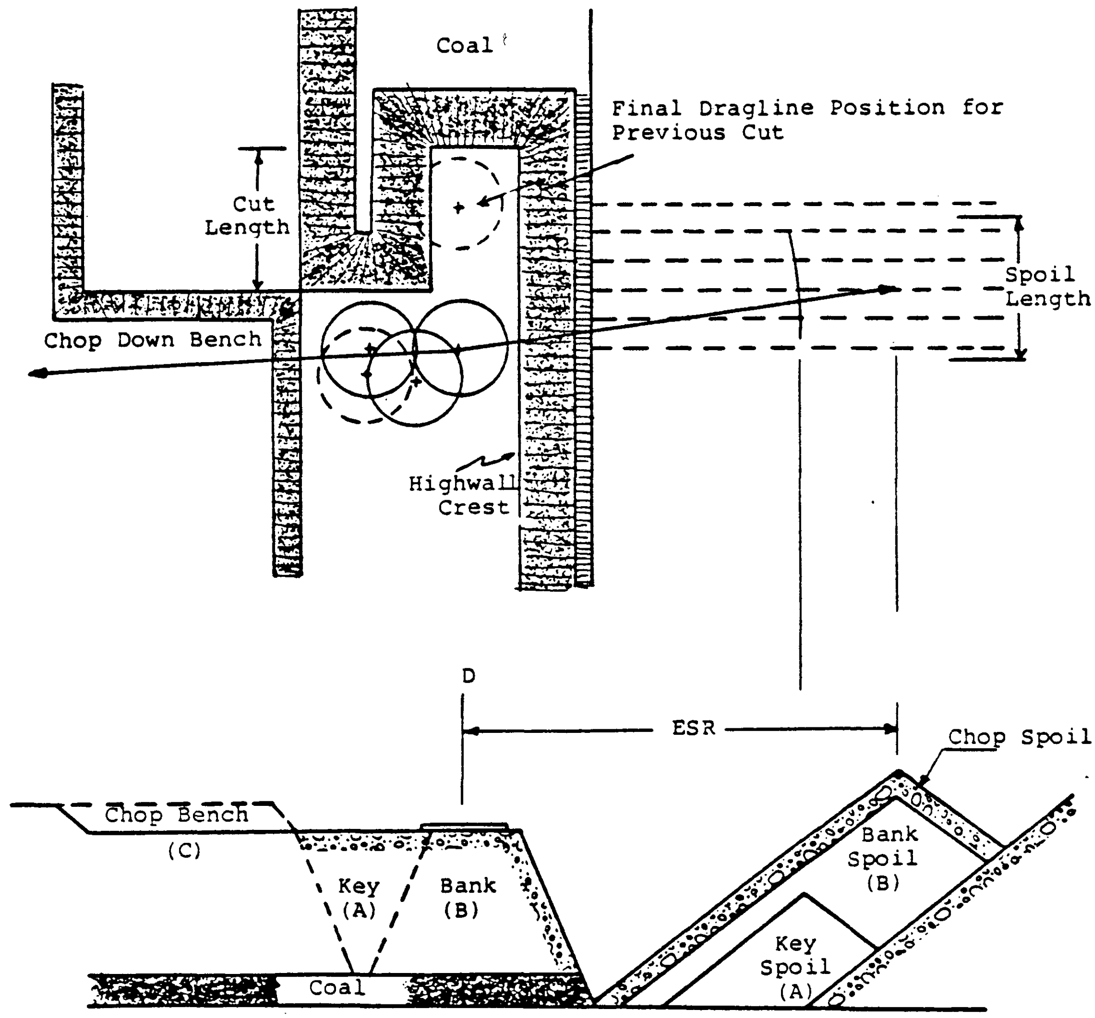


Figure 16 : Plan and Cross Sectional View of Dragline Positions for Chop Down Method for Selective Overburden Removal.

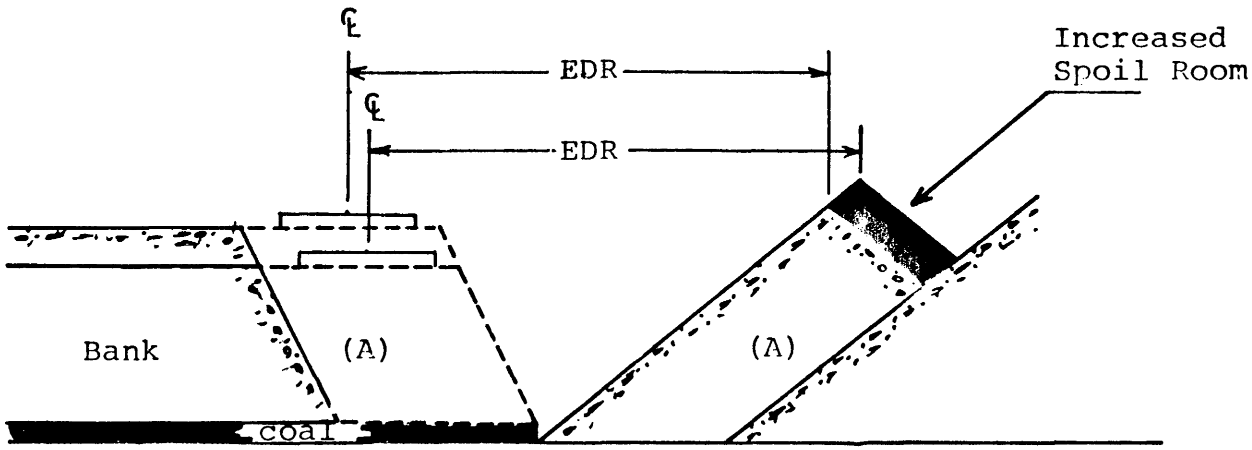


Figure 17. Effect of Chop Down on Dragline Reach.

there are a number of disadvantages. First, the chop down process used in cutting the side bench material is relatively inefficient. Since the machine is chopping down, the bucket fill factor may be considerably less than for normal digging. Chop down bucket fill factor is usually 70% compared to 90% for normal digging. Drag and fill time can be 20% more than normal (11). The swing angle required to spoil the chop down material is usually larger on the average, about 160 degrees. Due to these facts, cycle time for a dragline using chop down method is 40-50% longer than normal cycle times. The combination of longer cycle time and lesser fill factor reduces dragline production by 40-50% and increases stripping cost per ton of coal exposed. This becomes an important point to consider when deciding the quantity of the overburden which should be chopped down and how much of it should be moved by other methods such as extended bench.

Selection of the Dragline for Chop Down Method

The conventional approach to dragline selection for side casting can be applied to the chop down method with some modification.

Reach Determination

Before using the previously derived modified reach equation to determine the dragline reach for the chop down method, overburden height has to be adjusted to take the chop down bench height into consideration.

By chopping down a portion of the overburden, the dragline can move closer to the spoil pile because of the effect of the highwall angle. Yet, lowering the operating bench by chop down operation does not mean that spoil room gained by moving closer will provide enough spoil room to spoil all the material which is to be chopped. To calculate the effective overburden height reduction by chop down, the following equation is derived. For the derivation, refer to Figure 18.

Spoil Room Gained ADEB = Area CDFB - Area EDF - Area CAB

Area CDFB = CB x DK where

CB = W and

DK = W/2 · Tan B + X · Tan B

DK = (W/2+X) · Tan B (where X is the reach gained from the chop down)

Area CDFB = (W/2 + X) · Tan B · W

Area DEF = ACB = $\frac{W^2}{4}$ · Tan B

Therefore,

$$\text{Spoil Area Gained (ADEB)} = (W/2 + X)\ W \cdot \text{Tan B} \quad \bar{X}$$

$$2 \times \frac{W^2}{4} \ \text{Tan B}$$

Since:

$$X = \frac{CDBH}{TanA}$$

CDBH : Height of the chopdown bench

$$\text{Spoil Area Gained} = \left(\frac{W}{2} + \frac{CDBH}{TanA} \right) W \cdot \text{Tan B} - 2 \cdot \frac{W^2}{4} \ \text{Tan B}$$

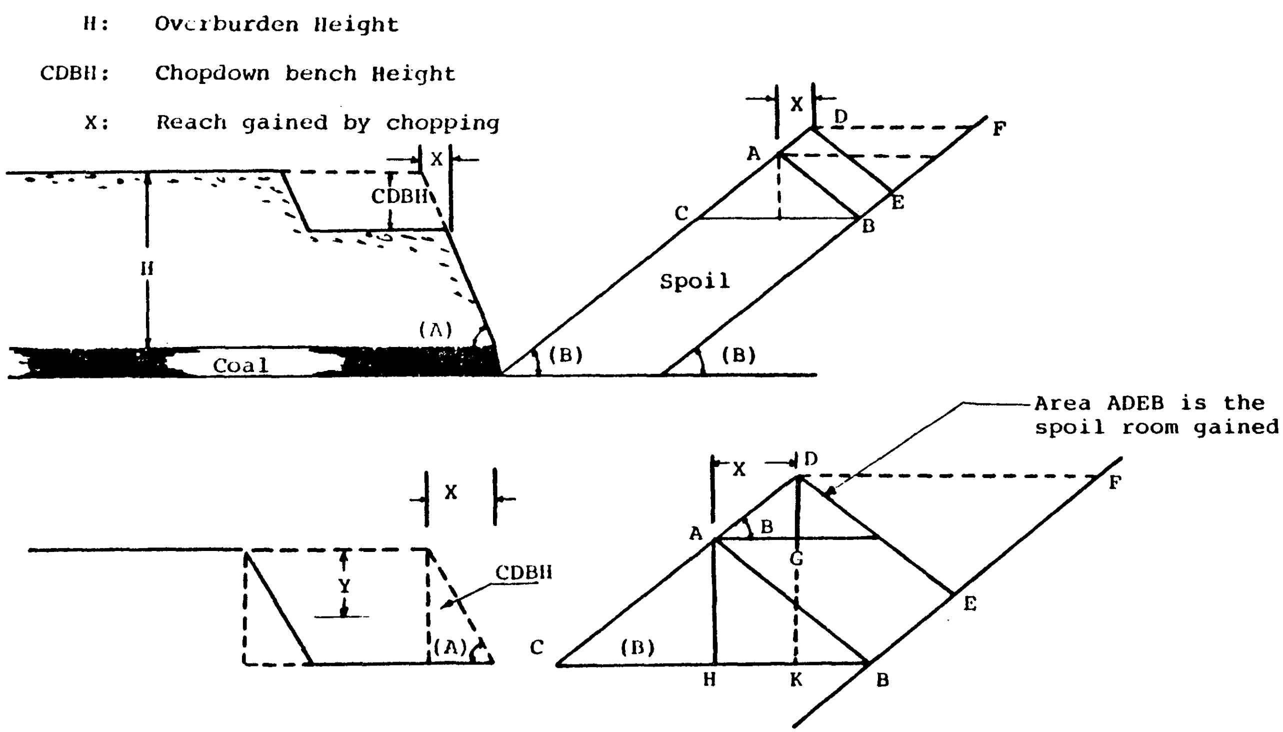


Figure 18 . Cross-Sectional view of a spoil room gained by chop down operation.

This spoil area gained can only hold overburden material with an area of:

$(W \cdot Y) \cdot (1+SF)$ Where Y is the effective overburden height reduction from the spoil room gained.

Then:

$$(W \cdot Y)\ (1+SF) = \left(\frac{W}{2} + \frac{CDBH}{TanA}\right)\ W \cdot Tan\ B - \frac{W^2}{2}\ Tan\ B$$

$$Y = \left(\frac{W}{2} + CDBH \cdot \frac{TanB}{TanA} - \frac{W}{2}\right) / (1+SF)$$

$$Y = \left(CDBH \cdot \frac{TanB}{TanA}\right) / (1+SF)$$

Once this effective height reduction, due to the chop down is determined, the reach equation for the chop down method becomes:

$$DOR = \left(\frac{(H-Y)}{TanA} + \frac{T}{TanC} + \frac{(H-Y)}{TanB} \cdot (1+S) + \frac{W}{4} + \frac{P}{4}\right) + \frac{X^2}{4\left(\frac{(H-Y)}{TanA} + \frac{T}{TanC} + \frac{(H-Y)}{TanB} \cdot (1+S) + \frac{W}{4} + \frac{P}{4}\right)}$$

Where Y is the effective height reduction

Bucket Capacity Determination

Bucket size determination of the dragline working with chop down method of digging involves the use of the standard excavator sizing equation previously discussed. Necessary adjustments should be made for cycle time and bucket fill factor to take inefficiency of the machine into consideration when it is chopping down.

EXTENDED BENCH METHOD

General Description

As the overburden begins to exceed the depth capability of a given machine, an amount of material must be rehandled in order to expose the coal seam. The extended bench method of stripping can be used to extend the effective spoil radius of the dragline. The dragline builds additional bench out from the crest of the highwall into the previous pit and uses this extra width to remove all the overburden by previously discussed side casting (Figure 19).

Key cut, and in the case of chop down and extended bench combination chop down bench material, is generally used to extend the working bench. To extend the bench, the dragline takes the material from the key cut, swings approximately 120 to 160 degrees and places this over the existing highwall in the direction of stripping advance. This is illustrated in Figure 19. This material is later leveled by a dozer to form a leveled dragline pad. After completion of the key cut, the dragline moves to outside position on the extended bench to remove the remaining material including the material handled previously in the process of extending the dragline bench.

In the extended bench operations, as the overburden depth increases, the amount of material to be rehandled will also increase.

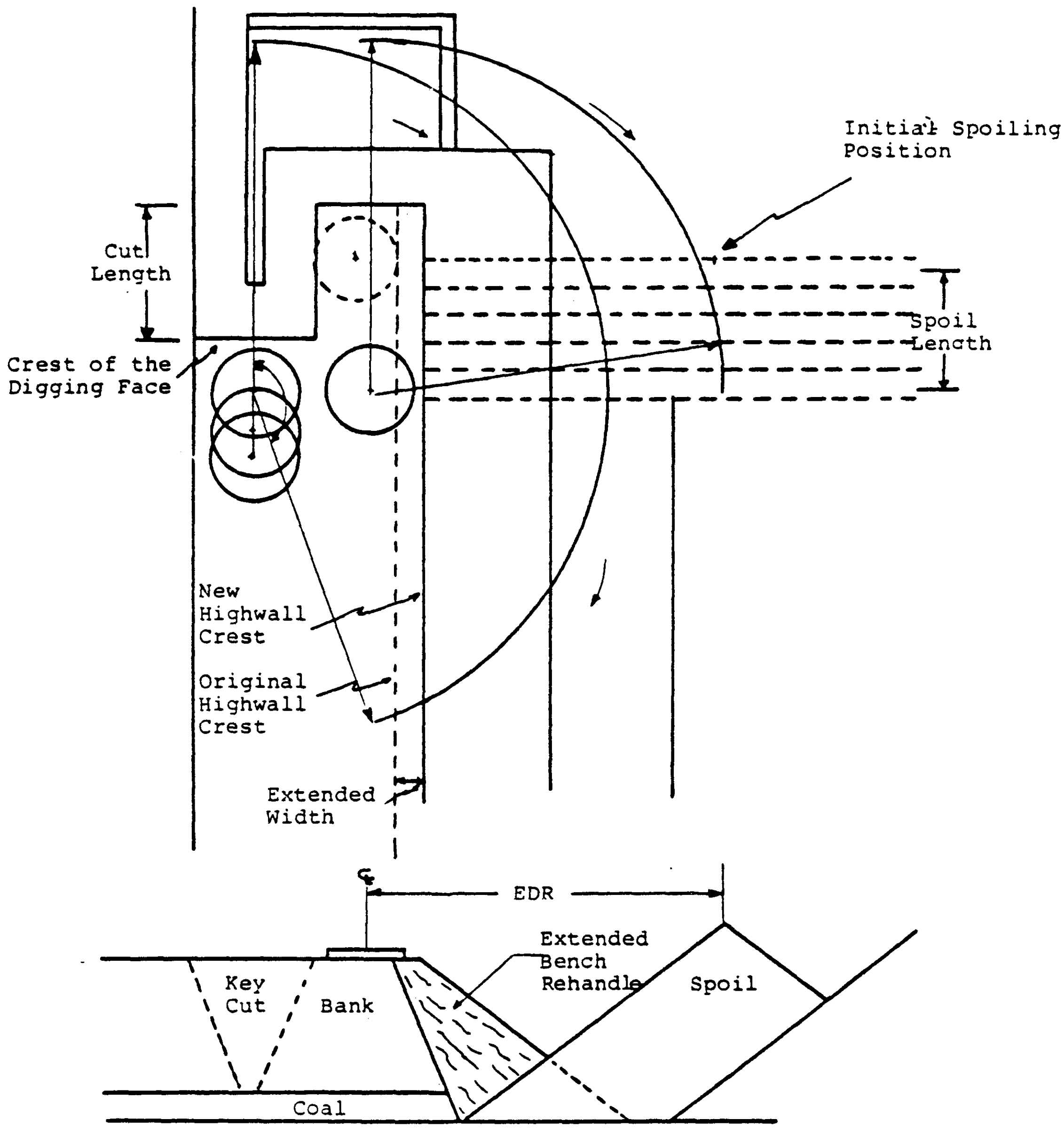


Figure 19: Plan and Section Views of Dragline Locations for Extended Bench Method.

Maximum rehandle acceptable for an operation is determined by the economics of the operation, and in general, percent rehandle should be kept to minimum.

Extended Bench With Chop Down

As previously discussed, the chop down method can be used to increase effective reach. As the depth of the chop down bench increases in a chop down/extended bench combination, the amount of rehandle decreases. Thus, in deep overburden, this combination can be employed to reduce the percent rehandle.

Plan and cross sectional views of dragline locations and typical method of extending the dragline bench using the material from the key and chop down are shown in Figure 20 and 21. As seen from Figure 20, dragline utilizes positions 1, 2 and 3 to remove and spoil the key cut material and also chop down material to extend the bench. From the positions 4 and 5 in the same figure, the remaining material is removed by side casting.

There are various alternative locations to get chop down material to extend the bench. For some operations, the dragline may chop down directly behind on the same pit. In other operations, the dragline chops down the bench half way over to the next pit. Although there is no most correct way of doing it, the swing angle for chop down may be minimized by chopping down the bench directly behind.

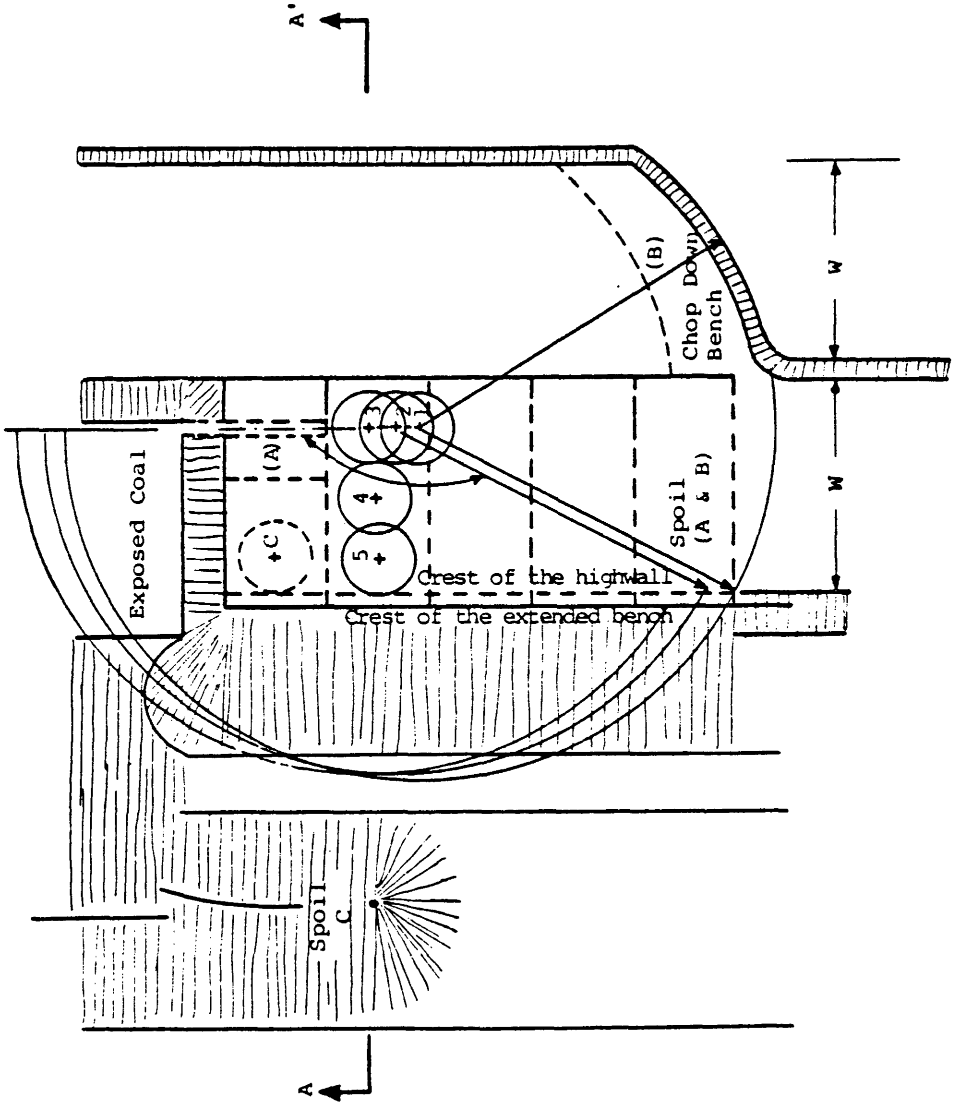


Figure 20: Plan View of the Dragline Locations For Extended Bench With Chop Down Method.

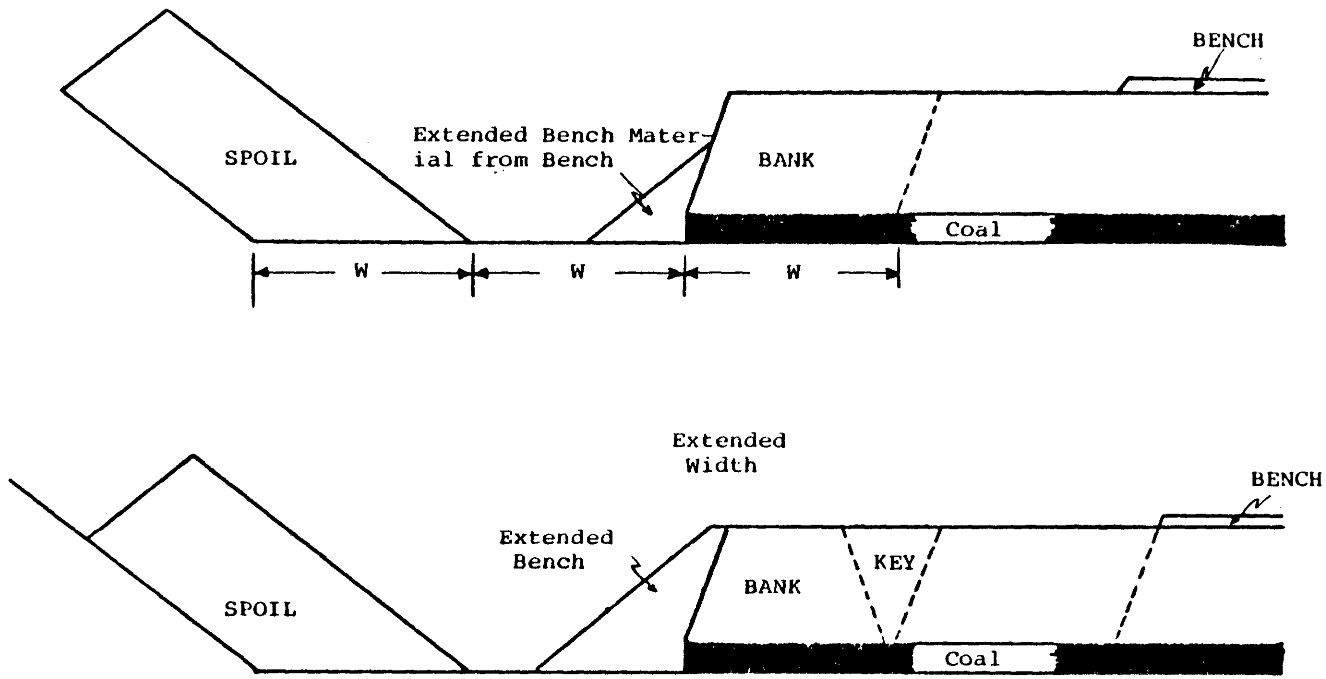


Figure 21: Cross Sectional Views of Bench Extention With Chop Down and Key Cut Material.

Calculation of Rehandle Volume for Extended Bench Methods

The amount of material rehandled due to bench extension is proportional to the overburden height that a given dragline will remove. The dragline operating radius required to remove a given overburden thickness without any rehandle can be determined from the dragline reach equation derived earlier for the side casting method. If the reach of the dragline is less than the required dragline reach, then the difference between the calculated reach and the actual dragline reach is the width the bench must be extended. The dragline must spoil adequate material to extend the bench. A portion of this material has to be rehandled in order to uncover the coal.

The calculation of this rehandle volume is discussed later in the model description of the extended bench method.

Selection of Dragline for Extended Bench Method

To select a dragline for a property on which the extended bench method will be used, various alternatives must be considered before making the final selection. The alternatives may involve choosing an overburden depth beyond which dragline will have to rehandle. Once the maximum overburden height to be used for the dragline selection is decided, the required dragline reach can be calculated.

The determination of bucket capacity involves calculation of the average percent rehandle for the entire property. Assuming that percentage of overburden material corresponding to various overburden depths are known, the percent rehandle for each overburden increment can be calculated. Weighting the percent rehandle based on percent reserve for each overburden increment, the average percent rehandle for the property will be obtained.

The annual overburden removal requirement is then adjusted by this percent rehandle before using the standard excavator sizing equation to calculate bucket capacity for the extended bench method. Cycle time should also be adjusted due to larger swing angles in extending the bench.

A detailed example of the dragline selection for extended bench is discussed later in the model application section.

PULL BACK METHOD

General Description

An alternate to the extended bench is the pull back method. The method can be employed with single or tandem machines.

In the tandem case, the primary machine works from the highwall and spoils the material into the previous pit by side casting. The second machine, usually smaller in size, is located on the spoil pile, pulling back some of the material in order to clear all the spoil from the coal. An illustration of this method is shown in Figures 22 and 23.

Before the second machine moves onto the spoil, a dozer prepares a leveled pad by knocking down the ridge of the previous spoil (Figure 23). Then the excess spoil is dug back away from the highwall and spoiled behind the dragline on the top of the previous spoil (Figure 23).

Dragline moving patterns and swing angles for the initial machine are same as for side casting method. But for the pull back machine the dragline operates with a swing angle of approximately 180° (1,15).

The amount of material to be rehandled determines the production of the second machine and furthermore, productivity of the machines must be carefully matched so they effectively operate as a team. The selection of the pull back machine will be discussed later in the model development.

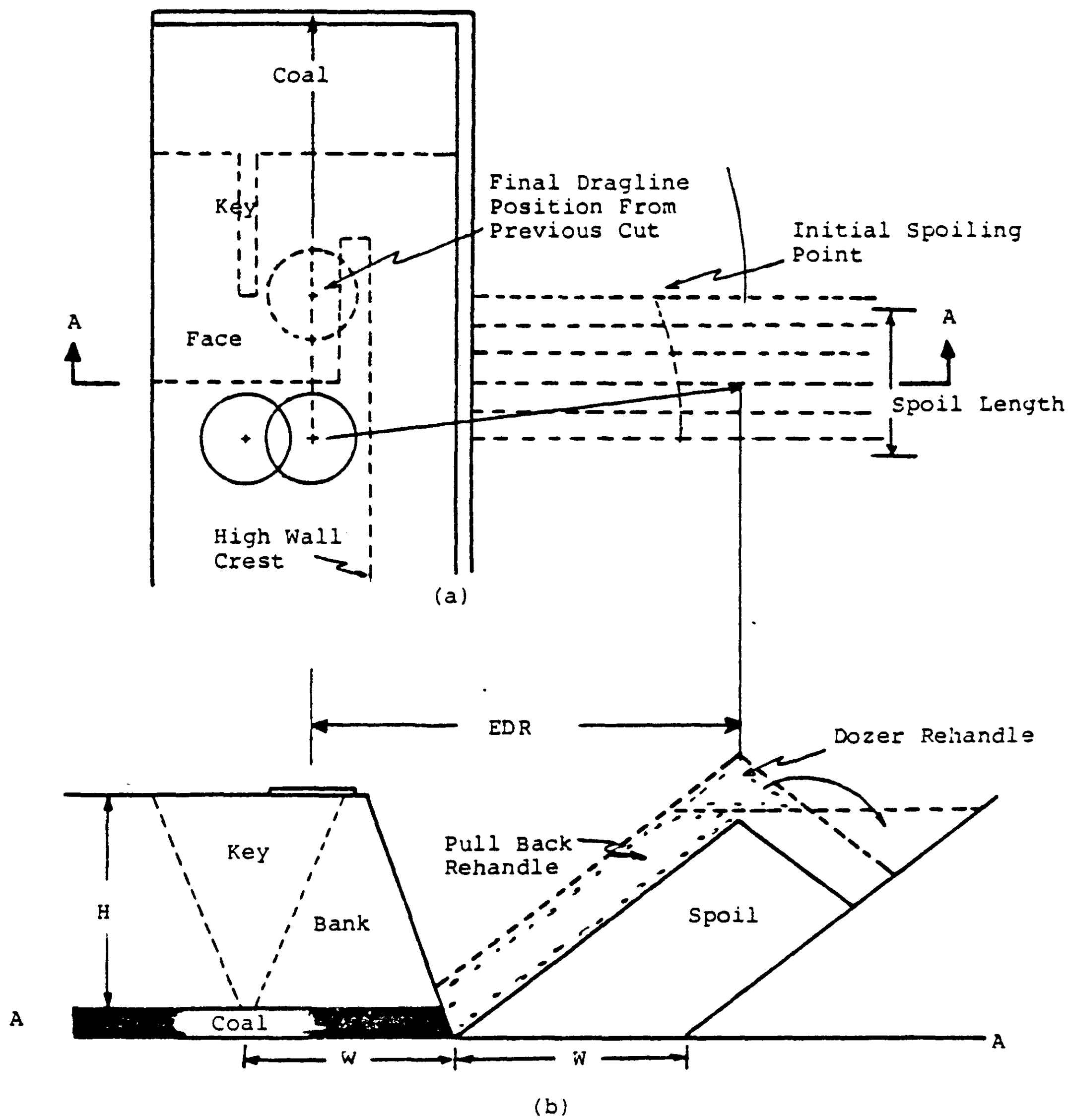


Figure 22: Plan and Cross Sectional View of the Primary Dragline Operation for Pull Back Method.

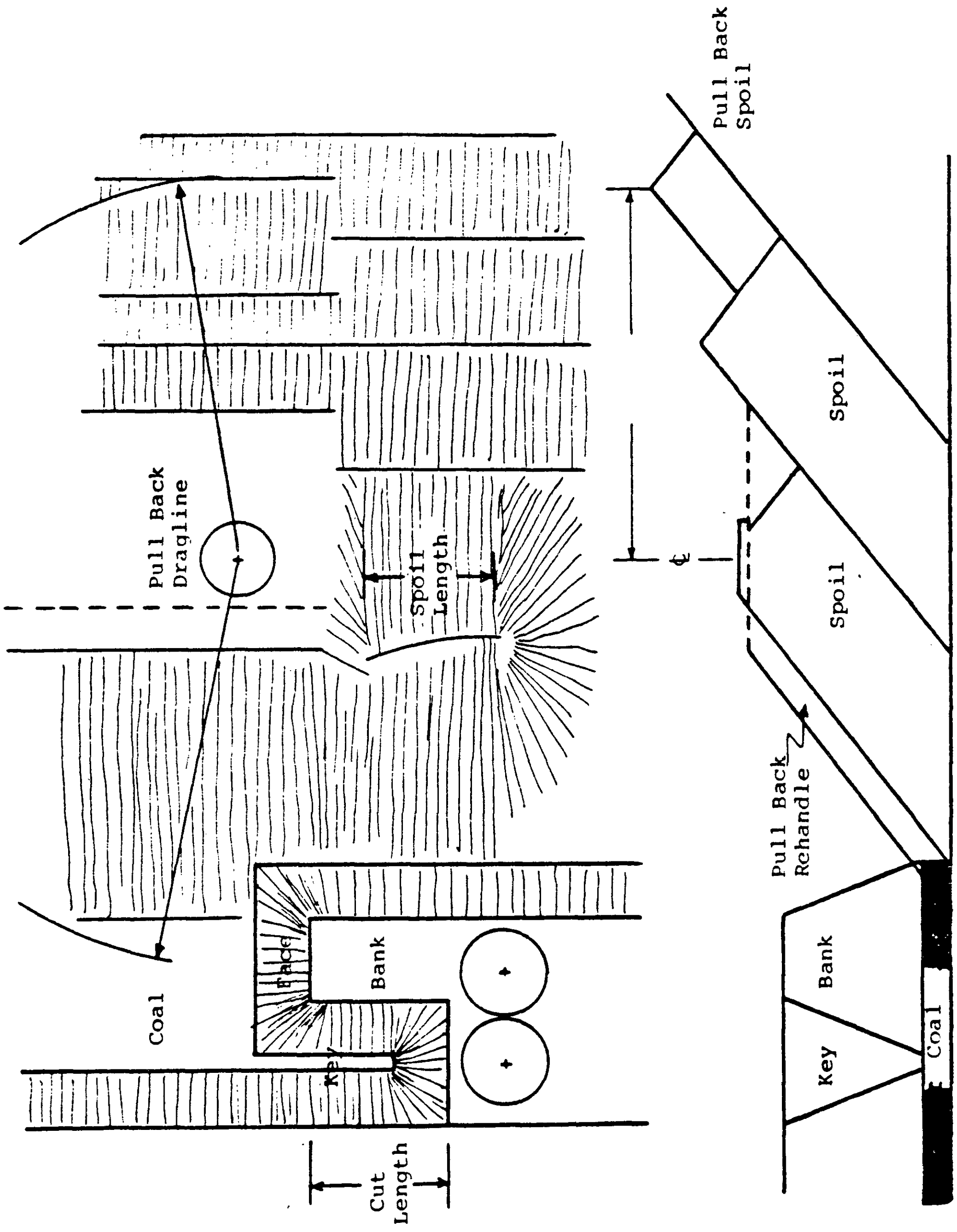


Figure 23: Plan and Cross Sectional View of the Pull Back Machine Operation.

MODEL DEVELOPMENT

In order to develop a dragline selection tool, it was necessary to construct a series of models which would estimate production for each of the methods previously discussed. Comparison of the various combinations of machine and method would be made on the basis of stripping cost per ton coal and required inclusion in the models of a cost estimating package. Since reserve data is generally available on the basis of tons per overburden increment, the costs and production for a specific machine could be combined on the basis of a weighted average where the weighting is a function of the percent coal in each overburden increment. Comparison and selection of the proper machine could be based on the machine which meets the required production at the lowest weighted average cost.

In order to develop a first approximation of the required machine, a selection model was developed which provides an estimate of the required reach and bucket size for the property assuming an average overburden depth and use of the side casting method. Draglines in this class can then be tested to determine the optimum machine.

General Approach

A deterministic simulation modeling approach was taken to evaluate dragline performance and cost for each stripping method. Each simulation model represents the stripping system by a set of mathematical equations and logical relationships which recognize property related, design related, and machine related variables.

Machine production is simulated by using the standard excavator production equation:

$$\text{Annual Production} = BC \times FF \times \frac{1}{1+SF} \times SH \times MA \times JF \times \frac{3600}{CT}$$

where:

BC = Bucket Capacity (yd^3)

FF = Fill Factor (%)

SF = Swell Factor (%)

SH = Scheduled Hours (Hours)

MA = Mechanical Availability (%)

JF = Job Factor (%)

CT = Cycle Time (Sec.)

The focus of these models is to determine the swing time component of the cycle time using a three dimensional approach, considering dragline positioning, digging location, and dumping location. The general dragline operating procedures used were previously discussed.

For each stripping method, models are designed to output pertinent information such as: average swing angle, average cycle time, walking time, volumes removed/dragline position, annual production, and owning and operating costs.

DISCUSSION OF INDIVIDUAL MODELS

General

As previously mentioned, variables for a given cut, such as pit dimensions, dragline positions, and digging and spoiling procedures directly affect the swing angle the machine must make to remove the overburden. Each dragline stripping method has characteristics associated with these variables. In the following sections, a discussion of each individual model development will identify these characteristics and how they are treated in each model.

Side Casting Model

The Side Casting Model assumes that the dragline is selected such that the machine reach is adequate to remove all overburden without rehandle.

The model considers dragline position, digging and spoiling procedures and dragline walking procedure for one cut in determining average swing angle and cycle time for the machine. Once the average cycle time is determined, annual machine output and ownership and operating costs per ton of coal uncovered and per cubic yard of overburden is calculated.

Overburden Removal

The overburden removal system in the Side Casting Model can be divided into two parts; removal of chop down material for bench preparation (optional) and removal of the main cut.

Chop Down Bench Removal

If a bench is used, the height and coordinates of the centroid for the bench must be defined. This overburden material is removed from the first dragline position in the walking sequence and spoiled at the bottom of the spoil area (Figure 24).

Main Cut Removal

The dragline can remove the main cut in either one lift or two lifts. If the overburden is thick and the top of the key is wider than the pit width, the dragline will remove the overburden in two lifts. In both cases, the dragline operates from various positions specified as input data. The dragline's positions and moving sequences required to remove the overburden for a one lift cut are illustrated in Figures 24 and 25. The dragline first makes a key cut from inside positions (Figure 24) and then moves closer to the highwall to remove the remaining material (Figure 25).

For the two lift cut removals the dragline first removes the top lift by making an initial key cut from the inside positions and then moves to the outside positions to complete removal of the top lift. After the top lift is removed, the dragline makes a key cut for the lower lift from the inside positions and then moves to the outside positions, to remove the remaining portion of the lower lift. Figure 26 illustrates two lift cut removals.

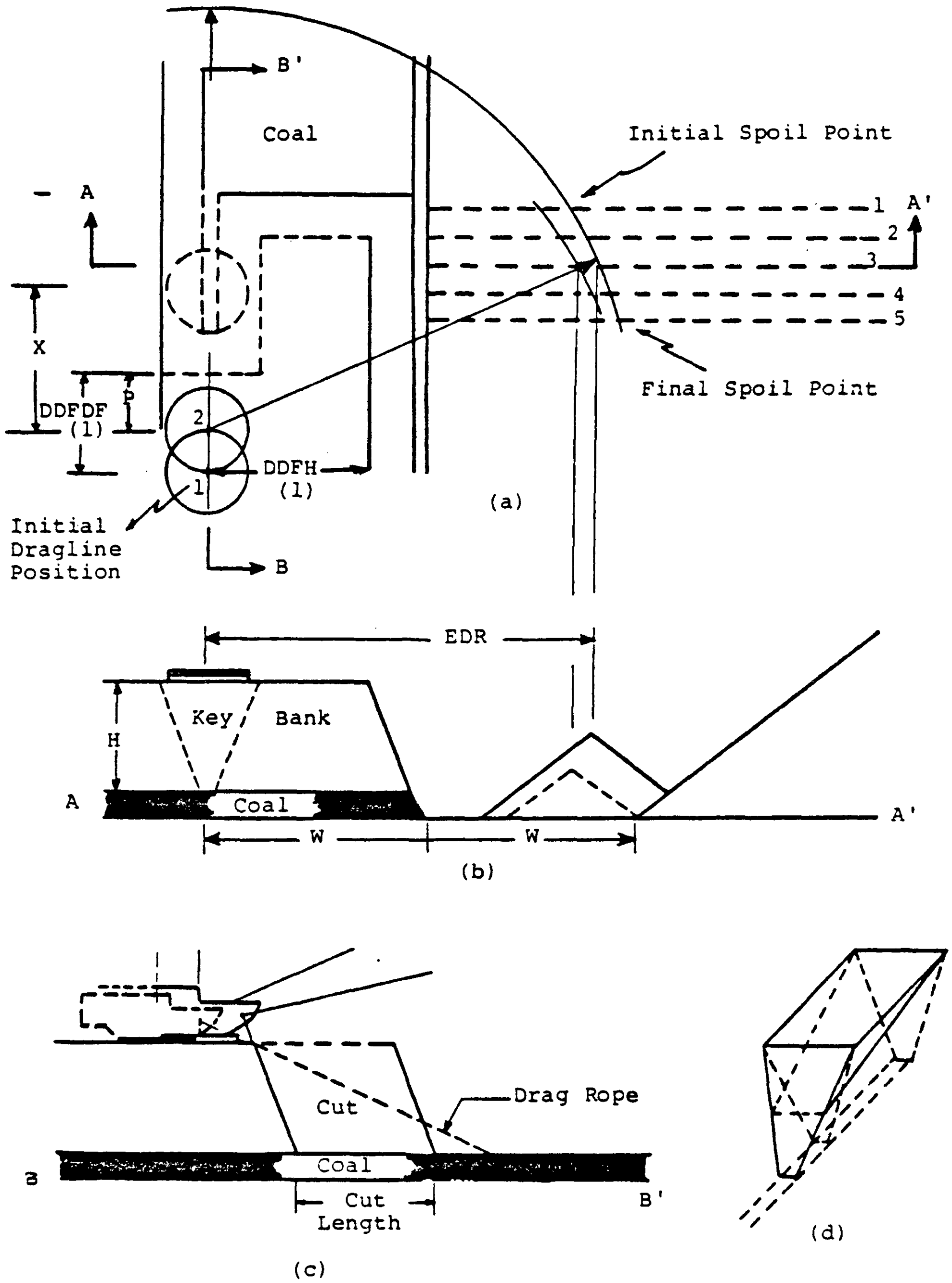


Figure 24: Plan and Cross Sectional Illustrations of the Pit Geometry for the Key Cut Removal for the Side Casting Model.

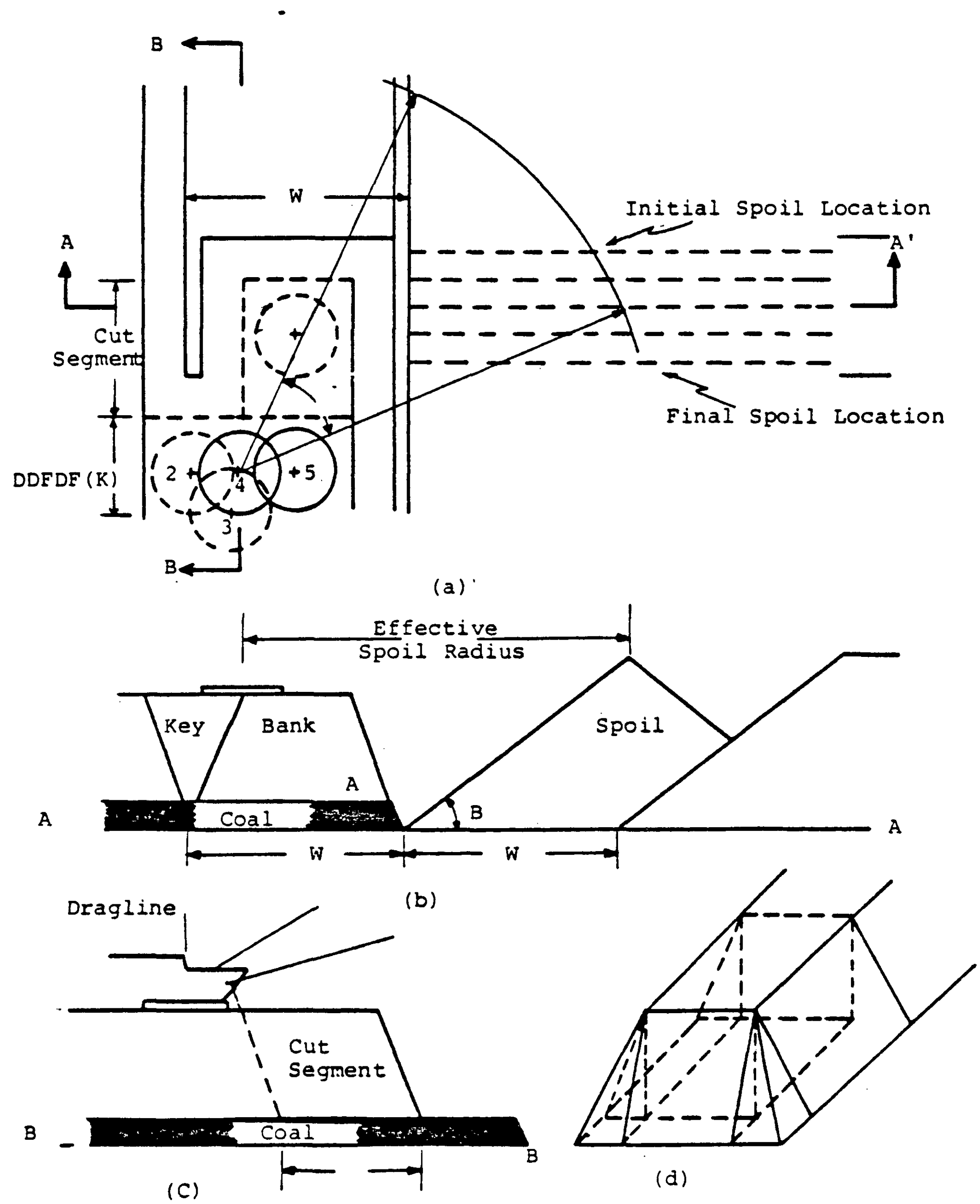


Figure 25: Plan and Cross Sectional Views of Pit Geometry for the Main Cut Removal of Side Casting Model.

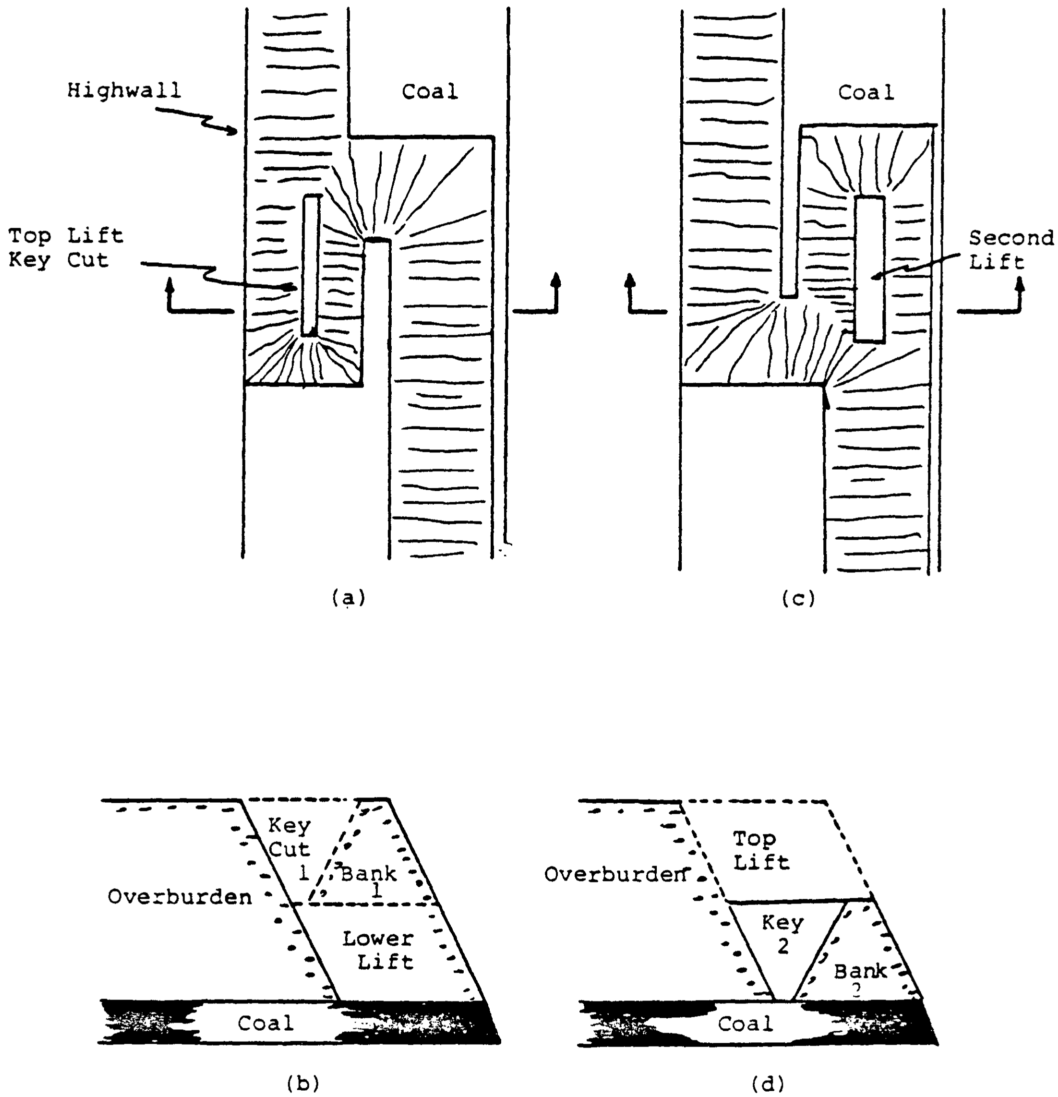


Figure 26: Two Lift Dragline Operation Shown in Plan View and Cross Sections. a and b Show the Top Lift, c and d Show the Bottom Lift.

Dragline Digging Procedure

The dragline digs the material at an angle determined by the distance of the dragline from the crest of the digging face and the height of the fairlead (6). Figure 27 illustrates various dragline positions in plan and cross-sectional views and how machine position determines the digging angle. As the dragline positions itself closer to the crest, the digging angle increases and the amount of material that can be removed will increase. Figure 28 illustrates digging angles with respect to machine positions.

Dragline Positioning

In the Side Casting Model, the user defines the dragline positions. A dragline position is defined as the perpendicular distance from the dragline center of rotation to the crest of the original digging face and to the crest of the highwall. When overburden is removed in two lifts, one set of positions for the first lift and a second set of positions for the second lift are required.

Overburden Volume Calculation

The overburden volume the dragline can remove from a given position is calculated with respect to the key and the main cut. Since the volume calculation for the key cut differs from the main cut, the dragline can only remove key cut material from the positions designated for key cut.

A detailed explanation of the volume calculation for

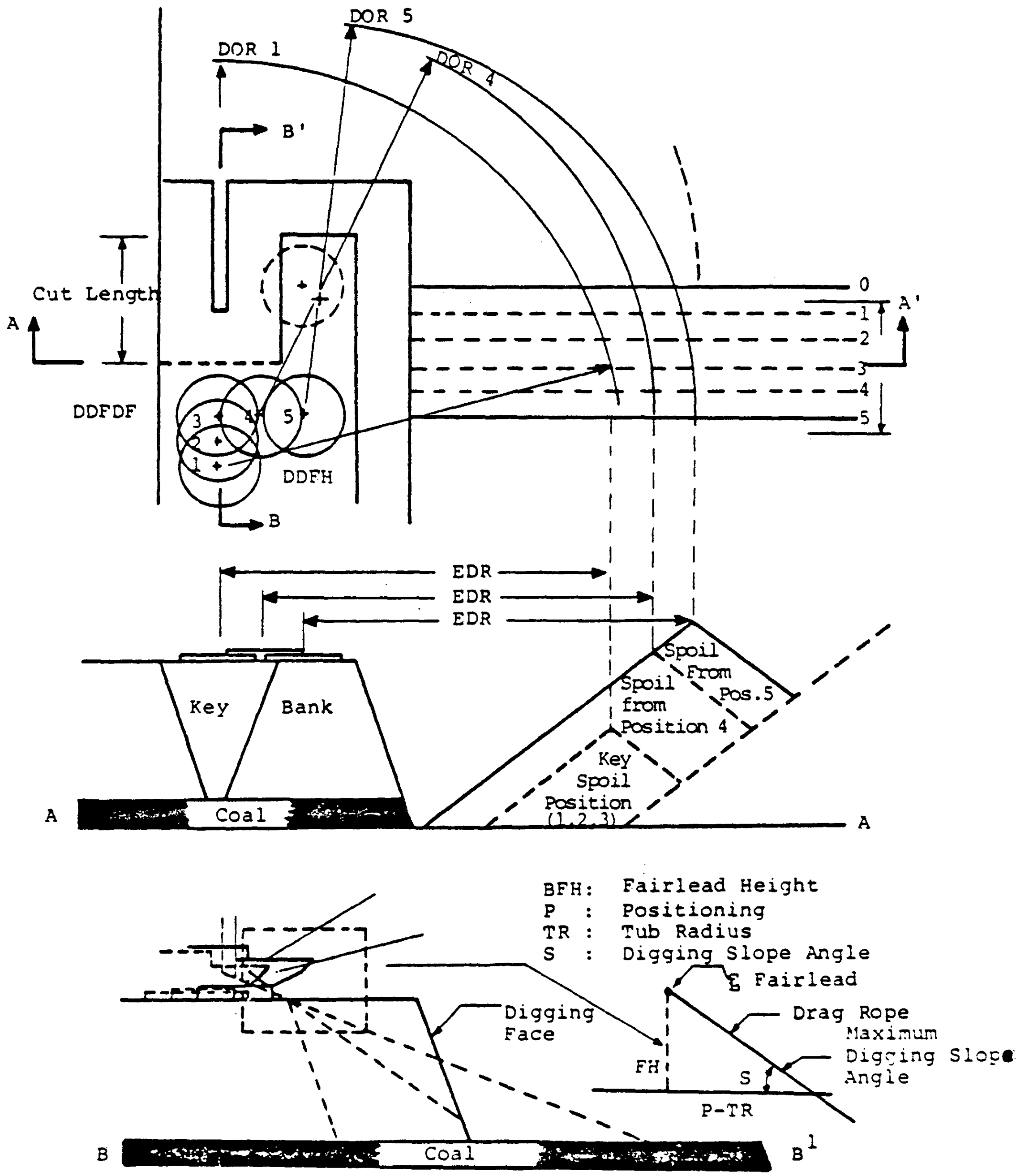


Figure 27 : Plan and Cross Sectional Views of Dragline Positions with Respect to Crest of Digging Face and Highwall.

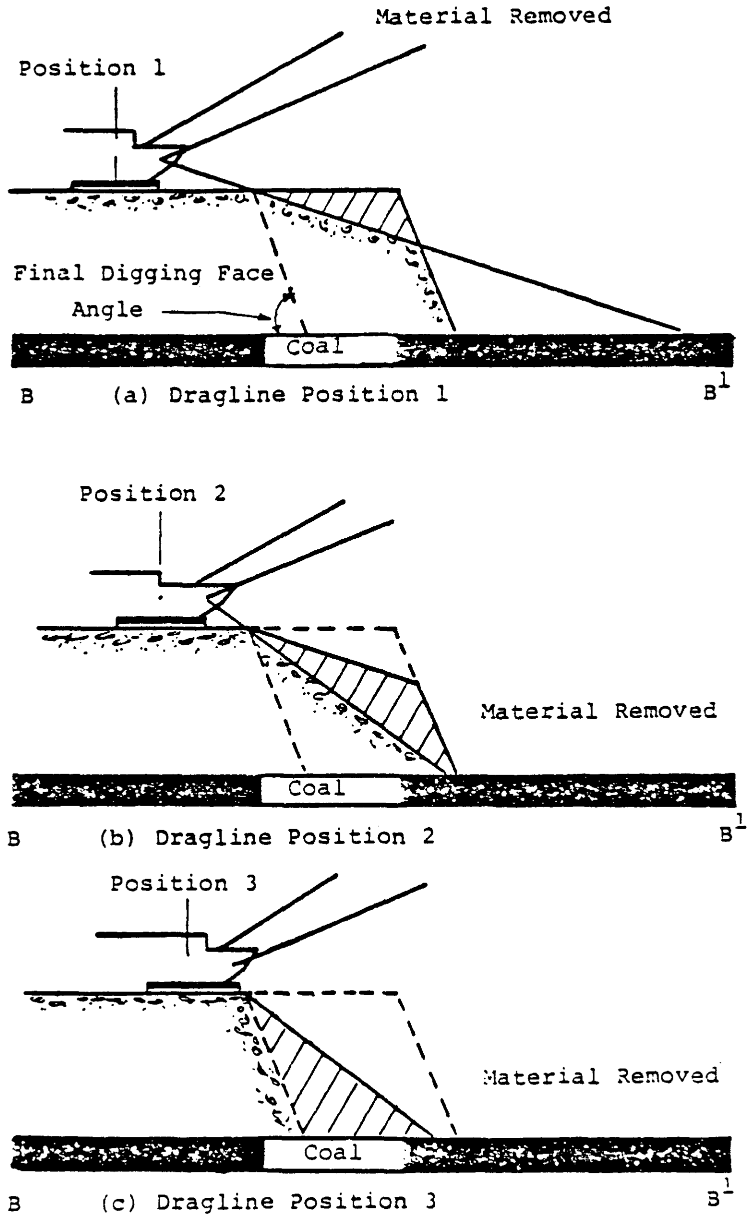


FIGURE 28: Cross Sectional Areas of Material Removed from Each Dragline Position to Make the Key Cut.

the key cut and the main cut is presented in Appendix A.

The overburden volumes are calculated from initial data and digging limits assigned to the dragline at each position from which it operates. In both key and prime cut, three different situations exist depending on the value of the digging angle and the dimensions of the cut. From Figures 29, 30 , 31 and 32 three cases must be considered in evaluating the areas excavated, as follows:

Case (a): Dug Area = Area 1 + Area 2 (Figure 30b)

Case (b): Dug Area = Area 1 + Area (2+3) - Area 3 (Figure 31b)

Case (c): Dug Area = Area 1 + Area 2 + Area 3 (Figure 32b)

Respective overburden volumes are then obtained by finding the products of cross-sectional areas and the corresponding widths across the cut.

Overburden Spoiling

Calculated overburden volume removed from a given position is spoiled along an arced ridge in the spoil area. The location of the spoil ridge is a function of the dragline's position and its operating radius. The dragline dumps several bucket loads over a period of time in the same location to build up the spoil pile to its capacity. The ridge location determines the apex of the cross sectional spoil areas. Therefore, the volume which can be spoiled from a position is directly proportional to the ridge location, as shown in Figure 33 and 34.

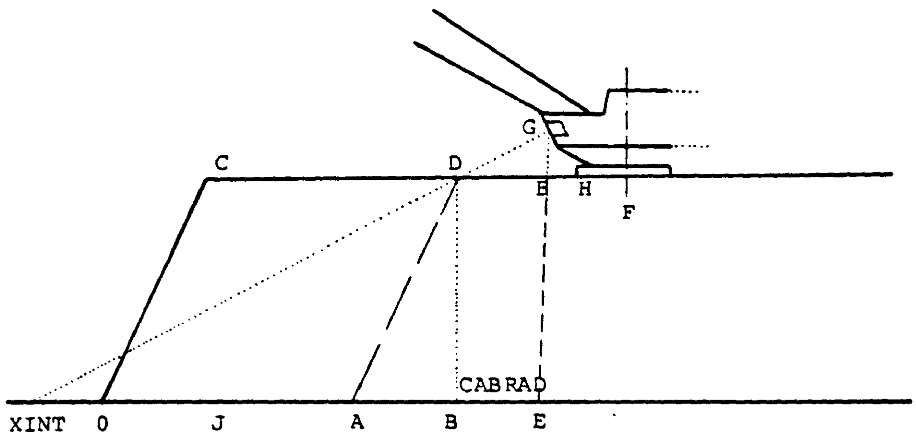


Figure 29: Dragline Digging Angle

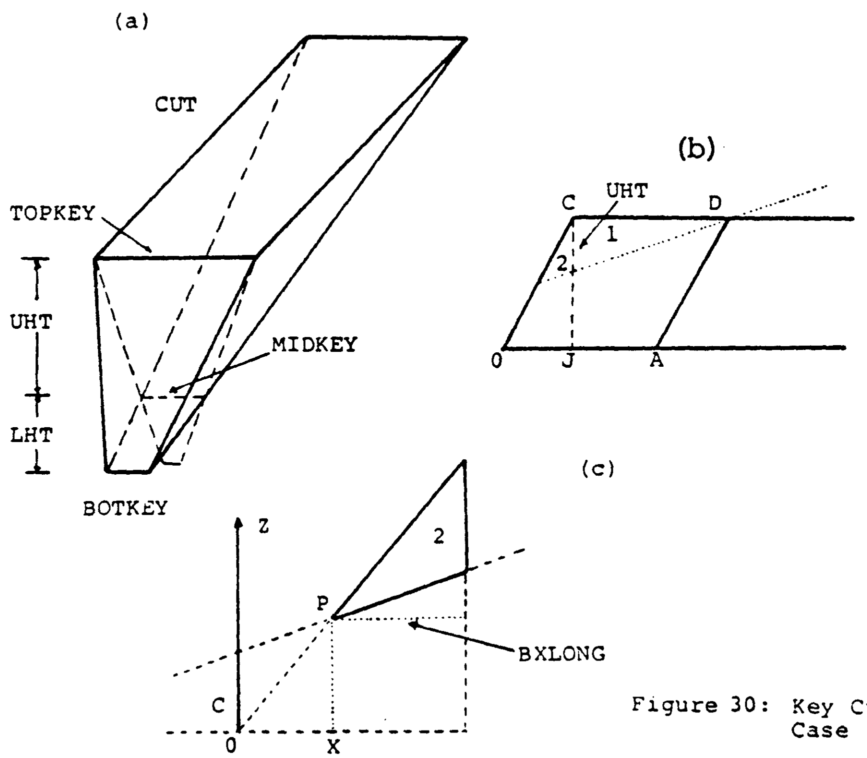


Figure 30: Key Cut Volume - Case (1).

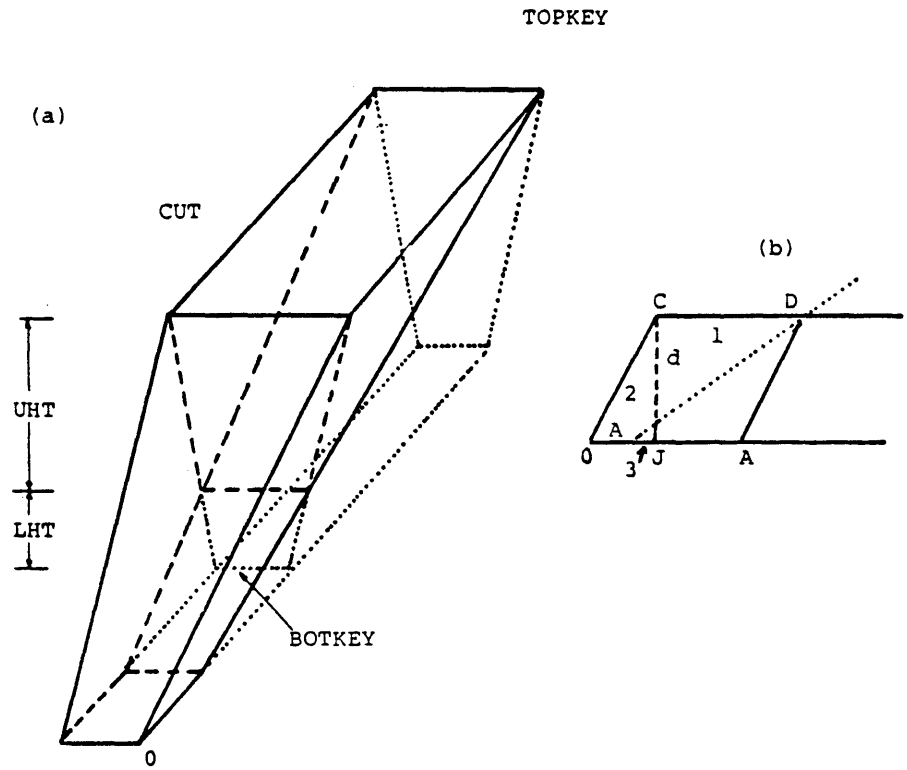


Figure 31: Key Cut Volume - Case (2)

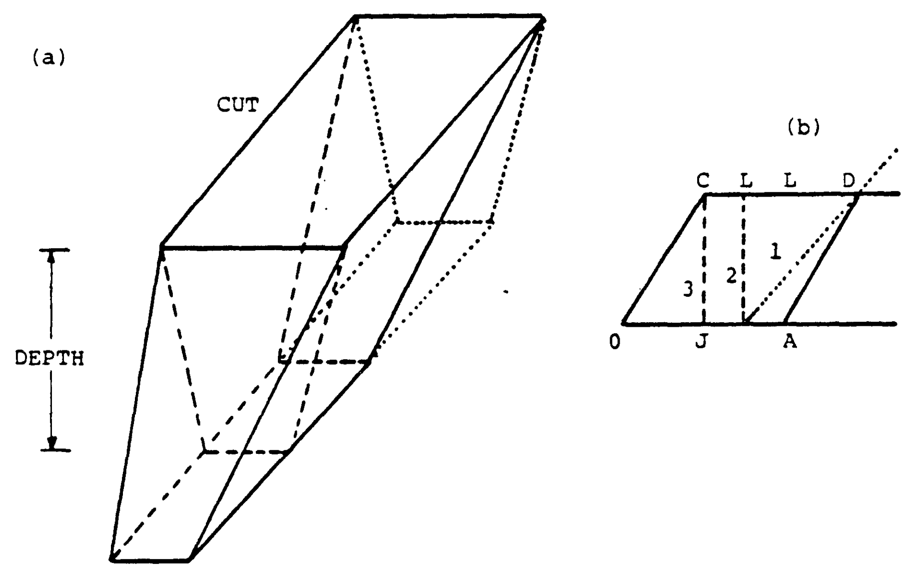


Figure 32: Key-cut Volume - Case (3)

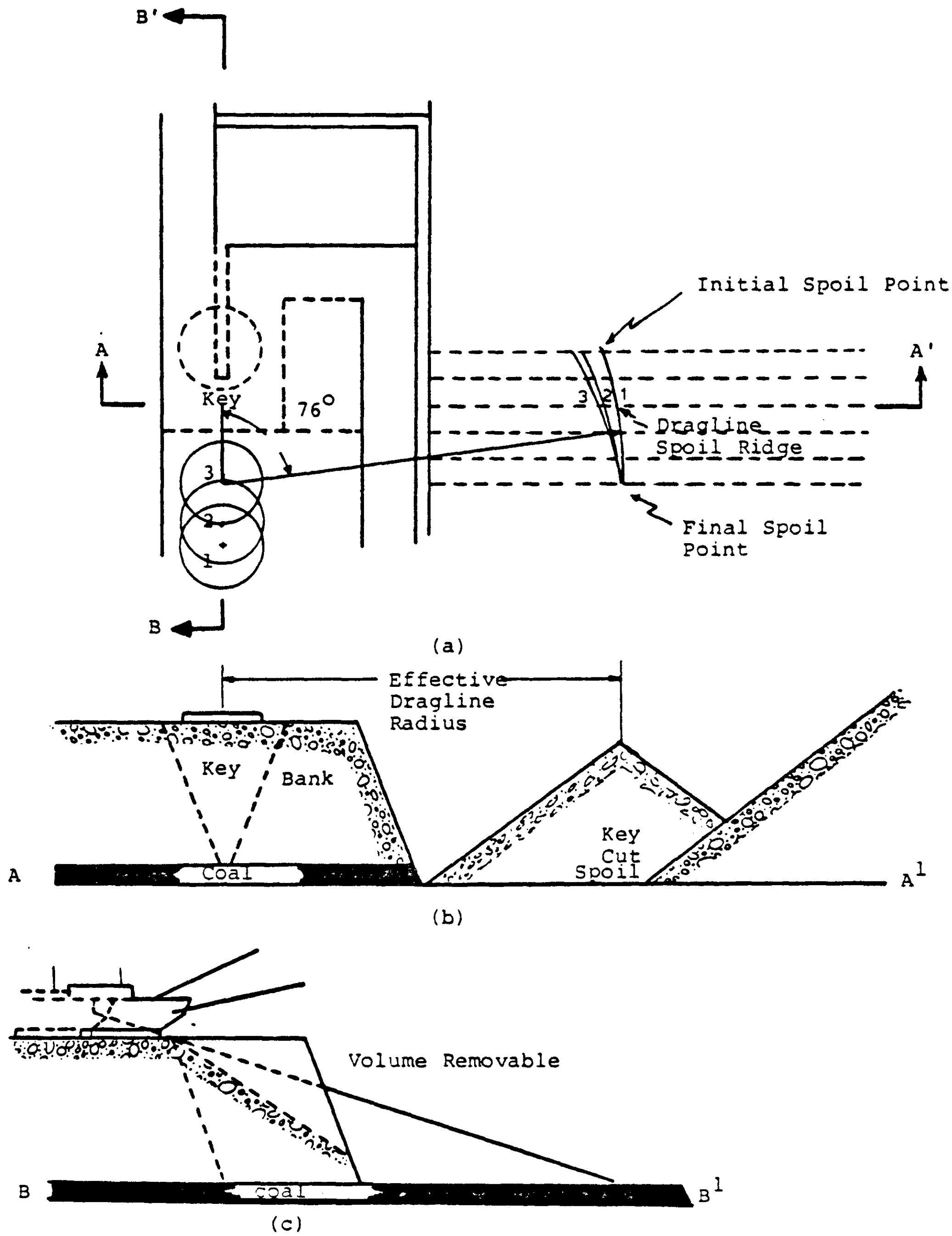


Figure 33: Dragline Spoil Ridge Location for Key Cut Position and Cross Section.

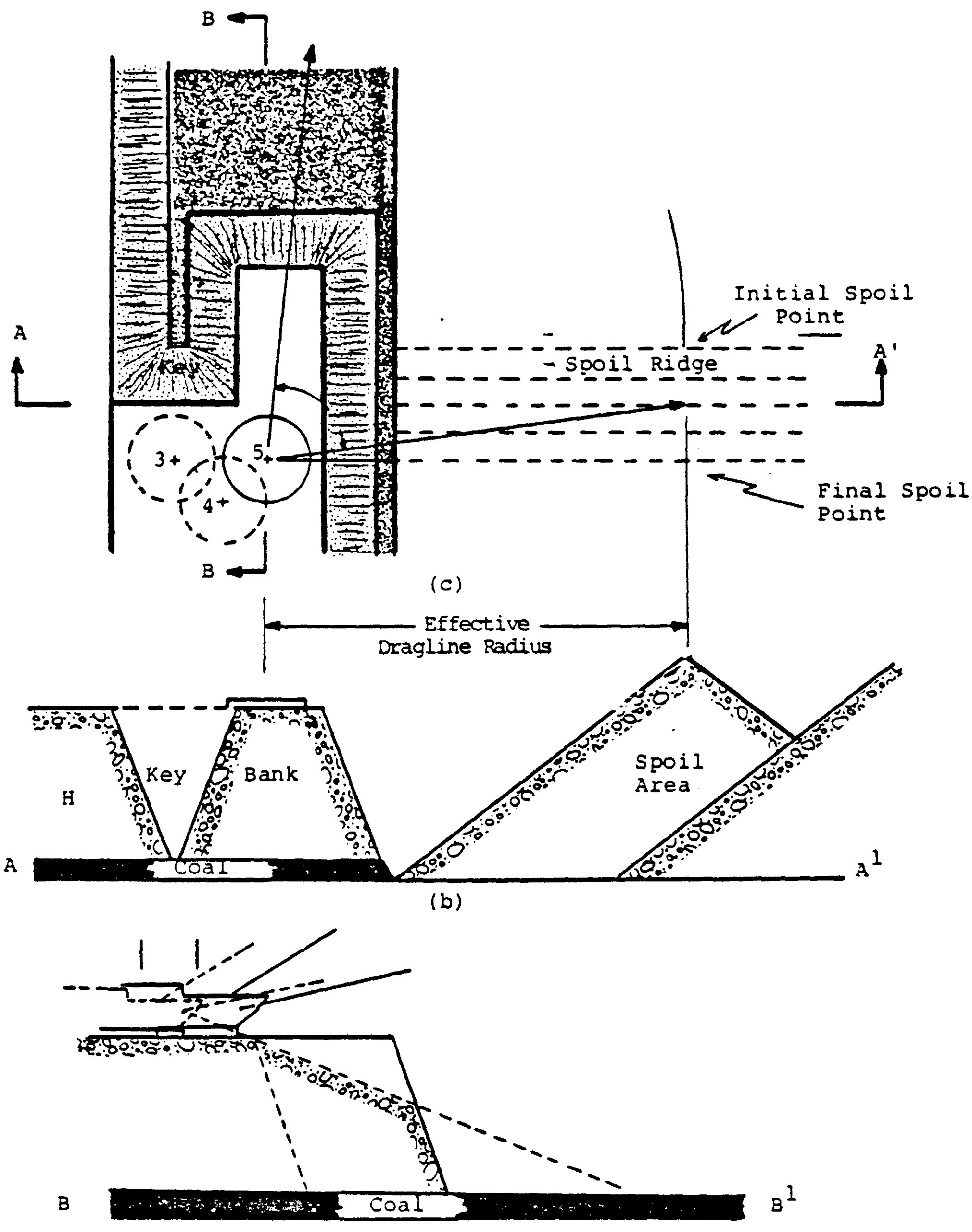


Figure 34: Dragline Spoil Ridge Location for Main Cut Position in Plan and Cross Section.

For a total cut volume, it is assumed in the model that the dragline spoils the overburden into the space in the spoil area which has a length along the pit equal to the cut length. The dragline starts spoiling from an initial point and gradually builds up the spoil pile along the curvature of the dragline radius in the allotted spoil space (Figure 33). Location of the initial spoiling point is critical and certain assumptions are made to determine it.

Initial Dumping Location For a Set-Up

Two cases must be considered in determining the initial dumping point in removing overburden in a set-up. In the first case, dragline reach is only sufficient for spoiling the given height of overburden. The model assumes that the dragline spoils on a curve governed by the operating radius of the machine and that the machine swings to a maximum of 90 degrees from the final digging position in a set-up. The initial dumping point is determined by the intersection of a line perpendicular to the highwall which passes through the center of rotation of the machine at the last digging position in the previous set-up and the operating radius of the machine from the first digging position of the present set-up (Figure 35). Overburden for this set-up is spoiled into the area bounded by lines perpendicular to the highwall passing through the centerline of rotation for the final position in the previous set-up and the final position in the current set-up as shown in Figure 35. The length (X) of this area is the same as

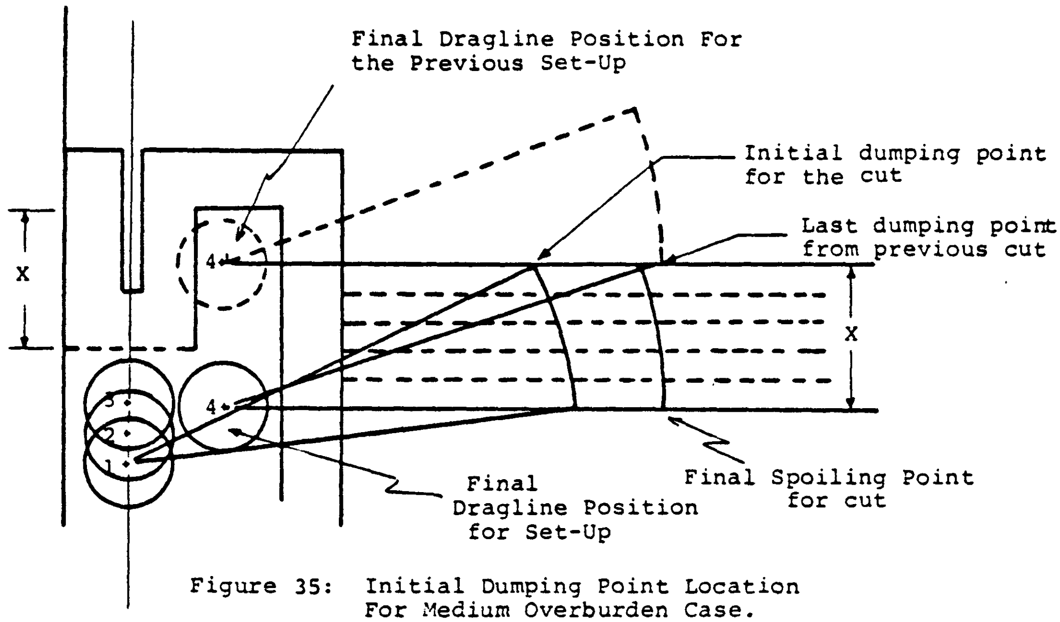


Figure 35: Initial Dumping Point Location For Medium Overburden Case.

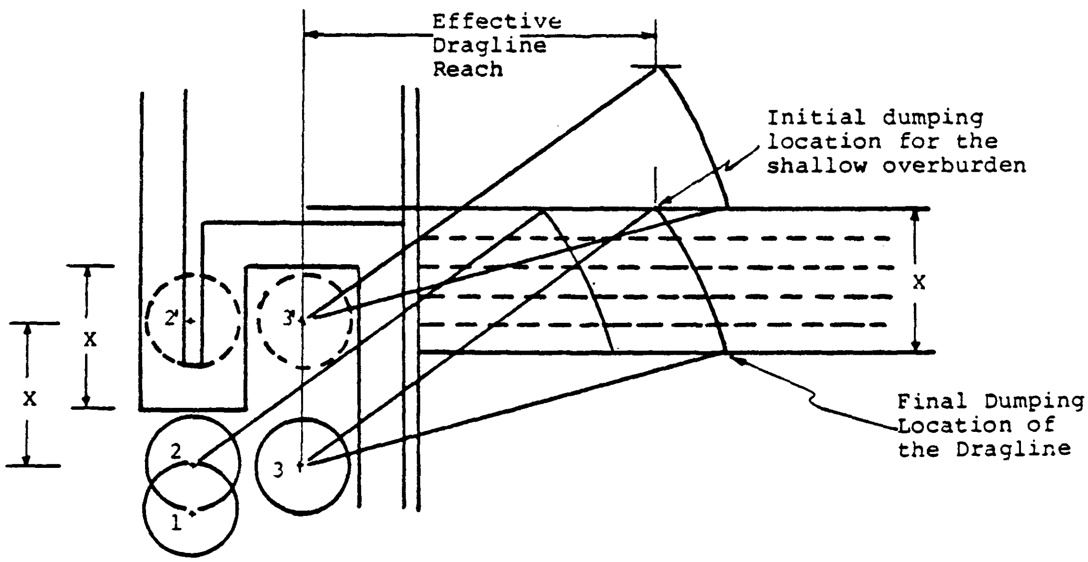


Figure 36: Initial Dumping Point Location For Shallow Overburden Case.

the set-up length.

In the second case, dragline reach is greater than that required to remove the overburden (shallow overburden). A smaller swing angle can be employed to spoil the material without rehandle. Initial dumping starts at a position where the machine can dump to some average required height and place all the spoil into an area with the specified set-up length. In locating the initial dumping point, the average required height is translated into a required effective dragline reach. Considering the final machine position in the set-up, the model determines the angle at which the effective reach could be obtained. This swing angle, in conjunction with the machine operating radius, defines the initial spoil location as illustrated in Figure 36 .

Spoil Volume Calculations

The model calculates the spoil volume capacity for a given set-up length from a number of cross-sections drawn through the spoil area perpendicular to the highwall. Each cross section represents a three dimensional slice of the spoil pile. The volume of each slice is calculated as the product of the cross-sectional area times the unit interval length between the cross-sections.

The model first checks the dragline location relative to the digging face and crest of the highwall. The overburden volume which can be removed from this position is then calculated. Overburden is placed into the first spoil slice with volume available until the capacity of that slice has been utilized. Sequential slices are filled until the overburden removable from that position has been spoiled. The volume of overburden in each slice is stored in a two dimensional array.

For the next dragline position, the process is repeated. The available capacity of each slice is re-calculated since this capacity is a function of the dragline position. The calculated capacity of a slice is adjusted by deducting the volume spoiled in the slice from the previous dragline positions.

Swing Angle Determination

The model calculates dragline swing angles on the basis of machine position in terms of center of rotation, the location of overburden removal, and the location of dumping from this position. It is assumed that the dragline will dump on the same point for a given spoil slice and machine position. For each dragline position, there are as many potential swing angles as cross sections.

The model weights the swing angle made for each slice with the amount of material spoiled in that slice. An average swing angle for a dragline position is calculated by dividing the product of swing angle and volume by the total volume spoiled from that dragline position.

Average Cycle Time Calculation

Cycle time is the cumulative time the dragline spends in loading the bucket, swinging over, dumping the bucket, swinging back and repositioning the bucket.

The model calculates the swing time as a function of swing angle and assumes the digging, dumping and bucket positioning and average delay times are constant for a given machine.

The model determines the swing time (two way) for a swing angle from the linear relationship defined by the user. Then, adding all the constant times to the swing time, total cycle time is calculated for the average swing angle made from a given position. The cycle times for the key cut and chop down are increased in the model by 50 percent due to the inefficiency of the dragline when making the key cut and chopping down (15,16,17).

To calculate overall average cycle time for a cut, the model includes dragline walking time from one position to the next position using an input walking rate and walking preparation time. Based on the average cycle time determined for a position, the model determines the time it would take the dragline to remove the calculated overburden.

A summation of the dragline time spent at each position, plus walking times, gives the total time required to remove overburden in one set-up. Total volume spoiled and total time spent to remove this overburden permits the model to determine overall average dragline cycle time for a given cut.

Ownership and Operating Cost Calculation

Dragline ownership and operating costs are determined as discussed in the first section of this thesis.

Ownership cost for the dragline includes depreciation, and interest taxes and insurance cost. The model calculates the dragline capital cost component by using either the straight line method of depreciation or capital recovery factor.

To calculate the dragline cost the user must define and input the following variables:

1) PCH - Power demand in an hour (KWH/HR)
2) PCKH - Power cost per kilowatt hour ($/KWH)
3) LR - Labor rates per hour
4) DIC - Dragline investment cost ($)
5) ITIP - Interest taxes and insurance percentage
6) CRF - Capital recovery factor (decimal fraction)

Based on these input variables, total dragline ownership and operating cost are determined, and expressed as costs per cubic yard and cost per ton of coal uncovered.

Computer Program

The computer program to execute the side casting model is written in FORTRAN IV to run on the Colorado School of Mines' DEC System 10 computer.

The program consists of a main program and three subprograms. The main program performs the following: inputs data; determines whether or not the dragline is operating in shallow overburden or medium overburden; determines whether or not a cut will be mined in one lift or two lifts; calculates walking distances; performs cost analysis for the dragline; and outputs the input data, operating characteristics and cost summary. The first subprogram calculates the cycle time for each position. The second subprogram calculates the removable volume for each key cut position, and the third subprogram calculates the removable volume for each main cut position.

Input Variables

The list of all the input variables, units, and their descriptions are included in Appendix D. Some of the more important input variables are described below:

Cut Segment Dimensions

The Figure 37 represents the cut profile and the dragline positions at the start of the simulation for the operation by the side casting model. It is expected that the user draws the cut profile and determines the dragline positions similar to Figure 37 before inputing the variables. The dimensions shown on this figure must be specified by the user for each simulation case to be run. The user specifies the dimensions shown in Table 4 to describe cut geometry.

Dragline Positions

The user inputs the coordinates for each dragline position for a given cut. Figure 37 shows an example drawing to illustrate dragline positions. The coordinates of the dragline positions are defined with respect to the crest of the highwall and the crest of the immediate digging face. The dragline positions must be numbered in sequence starting from the first

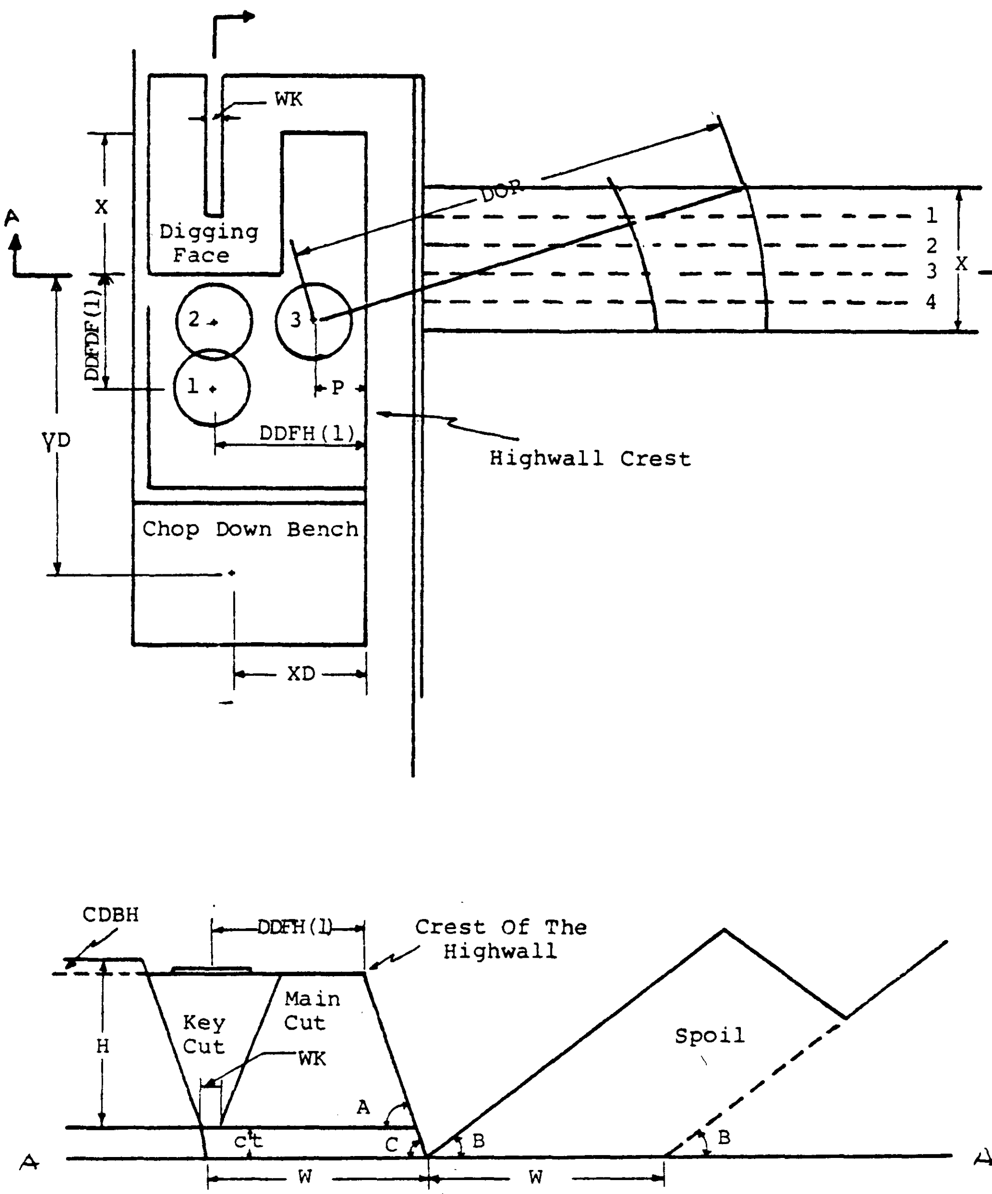


Figure 37: Model Variables Illustrated in Plan and Cross Section.

TABLE 4. INPUT VARIABLES FOR SEGMENT DIMENSIONS

NAME	DEFINITION	UNITS	DESCRIPTION
H	Height of the overburden.	Feet	This height is measured from the surface to the top of the coal. It is expected to be the average height for the area.
CT	Coal Thickness.	Feet	
A	Angle of the overburden highwall.	Degrees	
B	Angle of the overburden spoil.	Degrees	
C	Angle of the coal face.	Degrees	
SF	Swell factor of the overburden.	100	
X	Segment length.	Feet	This dimension is the length of the overburden the dragline will remove for a set-up.
W	Pit Width.	Feet	
WK	Width of the key.	Feet	This is the width of the key cut at the top of the coal surface.
CDBH	Chop Down Bench Height.	Feet	This is the height of the bench to be chopped down for bench preparation.
XD - X	Coordinate of the centroid for the chop down bench.	Feet	This dimension is the distance from centroid of the chop down bench segment to the crest of the highwall.
YD - Y	Coordinates of the centroid for the chop down bench.	Feet	This is the distance from centroid of the chop down bench to the crest of the digging face.

dragline position to make the key cut. When the cut is to be mined in two lifts, the dragline positions for the second lift must also be specified. The dragline positions for the second lift should be numbered as continuation of the first lift positions. Since the key cut volume calculation differs from the main cut, the dragline positions for the key cut should be specified as such.

The descriptions of the variables which are used to define the dragline positions and to specify the key cut positions are shown on Table 5 .

Setting Dragline Dimensions.

Figure 38 shows the important dimensions to be used for digging angle calculation. Their description follows:

1) CABHT - Cab Height (feet)
   This defines the height where drag ropes enter into the dragline frame.
2) CABRAD - Cab Radius (feet)
   The dragline tub radius is defined as cab radius
3) P - Positioning (feet)
4) FA - Face Angle (degrees)
   Maximum digging face angle

Input Data

All the variables necessary for the calculations are input in Free Format by the file, named SIDE.Data. Table 6 shows a sample data file. As explained earlier, input data includes a flag variable to control mining of a cut by one

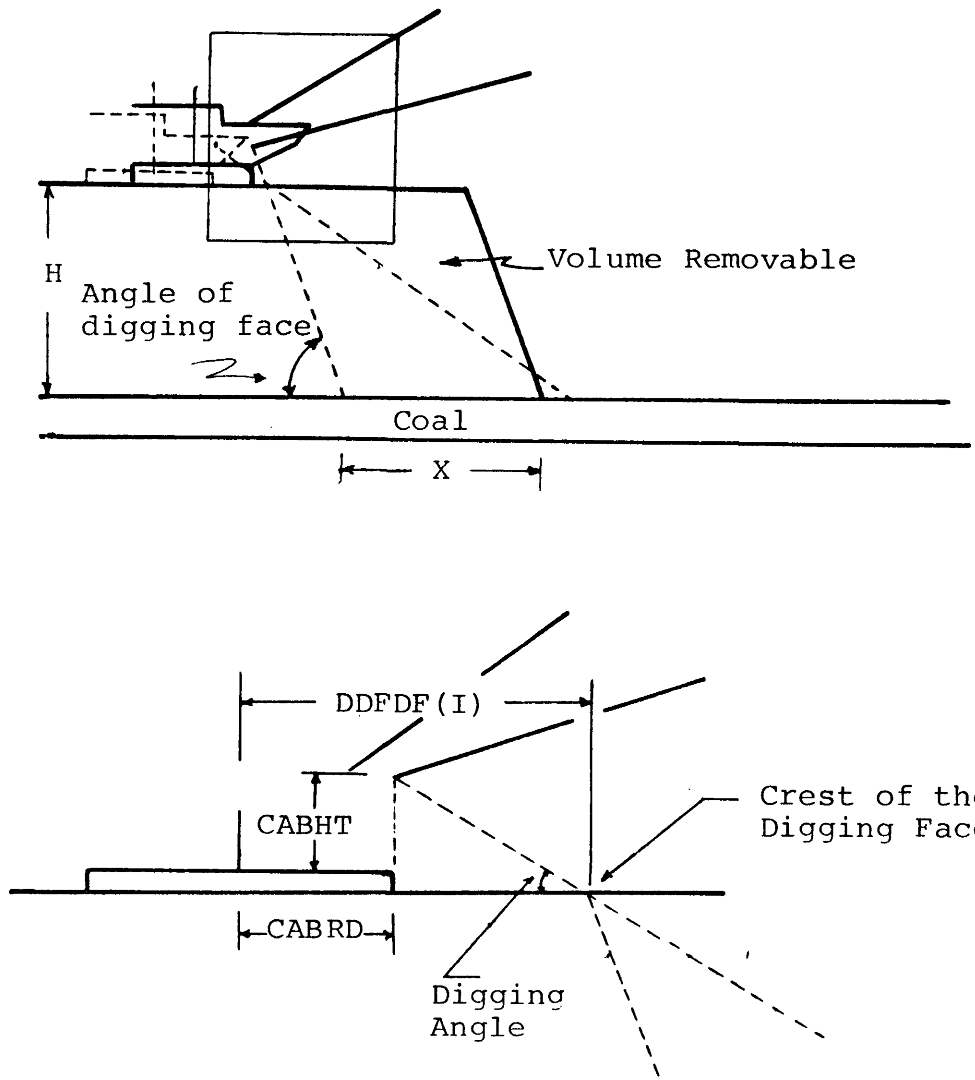


Figure 38: Dragline Variables To Determine Digging Angle Are Illustrated In Cross Section.

TABLE 5. INPUT VARIABLES FOR DRAGLINE POSITIONS

NAME	DEFINITION	UNITS	DESCRIPTION
DDFDF(J)	Dragline distance from digging face.	Feet	This defines the dragline location relative to the crest of the digging face for the Jth position. This dimension must be defined for each position.
DDFH(J)	Dragline Distance from Highwall.	Feet	This defines the dragline location relative to the crest of the high wall for the Jth position. This dimension must be defined for each position.
NPK	Number of Positions for Key.		This specifies the number of positions dragline will require to complete the key cut for one lift.
NTP	Number of Total Positions.		This specifies the total number of positions dragline will require to remove the whole cut in case of two lifts operation; this is the total number of positions to remove the top lift.
N	Number of Cross Sections.		The number of cross sections to be considered for spoil volume calculation is defined.
IFLAG	Control Variable.		This parameter is either set to 0 or 1. IFLAG = 0 - Cut segment will be mined in one lift. IFLAG = 1 - Cut segment will be mined in two lifts. When cut segment is mined in two lifts, new set of dragline positions must be entered for the second lift.

TABLE 5. (Continued)

NAME	DEFINITION	UNITS	DESCRIPTION
NFSIKP	Number for Second Initial Key Position.		This number specifies the initial position which key cut for the lower lift will be made. This number will be continuation of the numbers for the dragline positions for the first lift. For example if the number for last position happened to be 5, then NFSIKP will be 6.
NFSLKP	Number for second last key position.		This specifies the number for the last dragline position from which lower lift key cut will be completed.
NFST	Number for Second Total Positions.		This parameter specifies the total number of dragline positions to mine the whole cut by two lifts operation.

TABLE 6: SAMPLE INPUT DATA
FOR SIDE CASTING MODEL

```
H, W, CT, CD, A, B, C, FA, SF, X, WK
CDBH
XD, YD
MT
DR, BC, CABHT, CABRAD, P
DT, BPT, ST1, ST2, SCC, WS, CLT
SH, AV, JF, RF, FF
DIC, PCKH, PCH, LR, DOL, CRF, ITIP
NPK, NTP, N
DDFDF(1), DDFH(1)
DDFDF(2), DDFH(2)
DDFDF(3), DDFH(3)
DDFDF(4), DDFH(4)
DDFDF(5), DDFH(5)
IFLAG
NFSIKP, NFSLKP, NFSTP
DDFDF(6), DDFH(6)
DDFDF(7), DDFH(7)
DDFDF(8), DDFH(8)
```

```
[14:05:49]
50.,120.,5.57,71.,63.4,35.,76.,34.,22.,100.,10.
0.0
120.,250.
MAR-8050 23A
285.,56.,13.,21.5,40.
12.,12.3,40.,46.,18.,0.25,180.
6800.,.88,.85,.88,.95
14000000.,1650.,0.03,13.0,20.,0.0,.16
3,5,5
80.,90.
60.,90.
40.,90.
40.,70.
40.,40.
0
6,6,8
40.,90.
40.,70.
40.,40.
```

or two lifts. For the initial run flag should be set equal to 0. If the program determines that the cut cannot be mined in one lift, then the program signals the user that the cut must be mined in two lifts. Consequently the user inputs additional dragline positions to mine the second lift. The input variables to specify the first key cut position number, last key cut position number and total number of positions to mine the two lifts should be entered as the next line after the flag variables. In the following lines the coordinates of each dragline position for the second lift can be entered one at a time.

Model Output

Sample output is illustrated in Table 7. The output variables are self explanatory, and therefore they will not be discussed any further.

Model Flow Chart

The model flow chart is presented in Figure 39.

Dragline Selection Model

The Dragline Selection Model is designed to determine dragline operating radius and bucket capacity to meet a required annual production. The model assumes that dragline will remove the overburden with the side casting method and simulates its

TABLE 7: SAMPLE OUTPUT OF THE SIDE CASTING MODEL

PROPERTY CHARACTERISTICS

OVERBURDEN HEIGHT	:	50.0	FT
COAL THICKNESS	:	5.6	FT
HIGHWALL ANGLE	:	63.4	DEGREES
SPOIL ANGLE OF REPOSE	:	35.00	DEGREES
COAL HIGHWALL ANGLE	:	76.00	DEGREES
SWELL FACTOR	:	122.00	%
COAL RECOVERY	:	88.00	%
PIT WIDTH	:	120.00	FT
CUT LENGTH	:	100.00	FT
CHOP DOWN BENCH HEIGHT	:	0.00	FT
PIT EXTENTION	:	0.00	FT

DRAGLINE CHARACTERISTICS

DRAGLINE TYPE	:	MAR-8050 2	
DRAGLINE REACH	:	285.00	FT
BUCKET CAPACITY	:	56.00	CUBIC YARD
SCHEDULED HOURS	:	6800.00	HOURS/YEAR
MECHANICAL AVAILABILITY	:	88.00	%
JOB FACTOR	:	85.00	%

DRAGLINE PRODUCTION AND COST SUMMARY

AVERAGE SWING ANGLE	:	56.60	DEGREES
AVERAGE CYCLE TIME	:	63.92	SECONDS
PRODUCTION RATE	:	2979.20	CU. YD/HR
TOTAL VOLUME SPOILED	:	15153403.0	CU.YD/YEAR
PRODUCTION RATE (BANK)	:	2441.97	CU. YD/HR
TOTAL VOLUME SPOILED (BANK)	:	12420822.0	CU. YD/YR
TOTAL VOLUME CHOPPED	:	0.00	CU.YD/YEAR
TOTAL VOLUME REHANDLED	:	0.00	CU.YD/YEAR
PERCENT REHANDLED	:	0.00	%
PERCENT CHOP DOWN	:	0.00	%
TOTAL COAL MINED	:	1167106.00	TONS
OPERATING COST	:	1.27	$/TON
	:	0.07	$/CU. YARD
OWNERSHIP COST	:	1.60	$/TON
	:	0.09	$/CU. YARD
TOTAL COST	:	2.87	$/TON
	:	0.17	$/CU.YARD

TABLE 7: (Continued)

DRAGLINE PRODUCTION SUMMARY
FOR
EACH POSITION

POSITION	1	2
VOLUME SPOILED (CU. YD)	3634.22	2270.20
AVERAGE SWING ANGLE (D)	41.93	47.93
EXCAVATING TIME (HRS)	1.44	0.91
WALKING TIME (HRS)	0.22	0.07
TOTAL TIME (HRS)	1.65	0.98
POSITION	3	4
VOLUME SPOILED (CU. YD)	2011.61	19195.09
AVERAGE SWING ANGLE (D)	53.34	60.74
EXCAVATING TIME (HRS)	0.82	5.44
WALKING TIME (HRS)	0.07	0.07
TOTAL TIME (HRS)	0.89	5.52
POSITION	5	
VOLUME SPOILED (CU. YD)	0.00	
AVERAGE SWING ANGLE (D)	0.00	
EXCAVATING TIME (HRS)	0.00	
WALKING TIME (HRS)	0.00	
TOTAL TIME (HRS)	0.00	

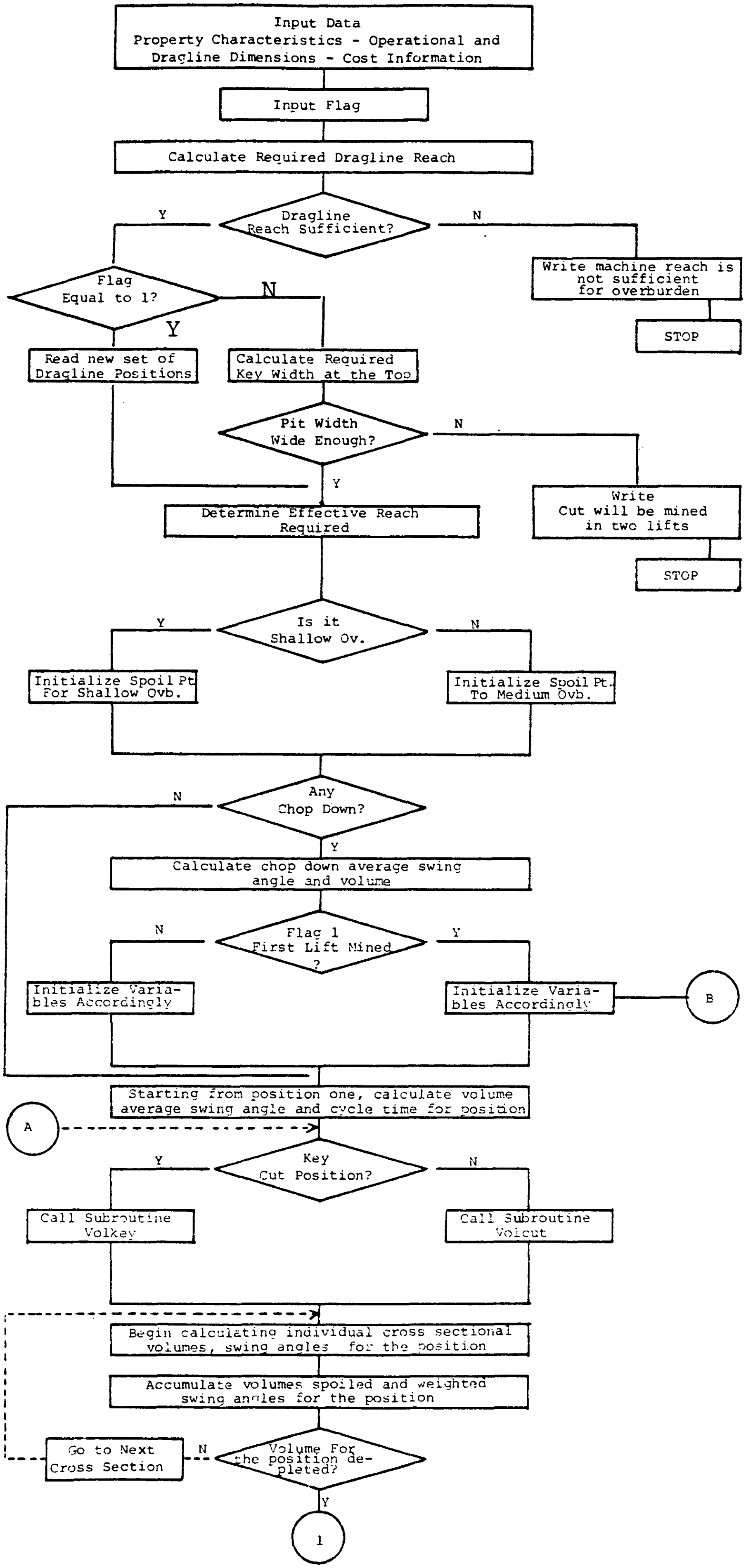


Figure 39: Computer Flow Chart For the Side Casting Model

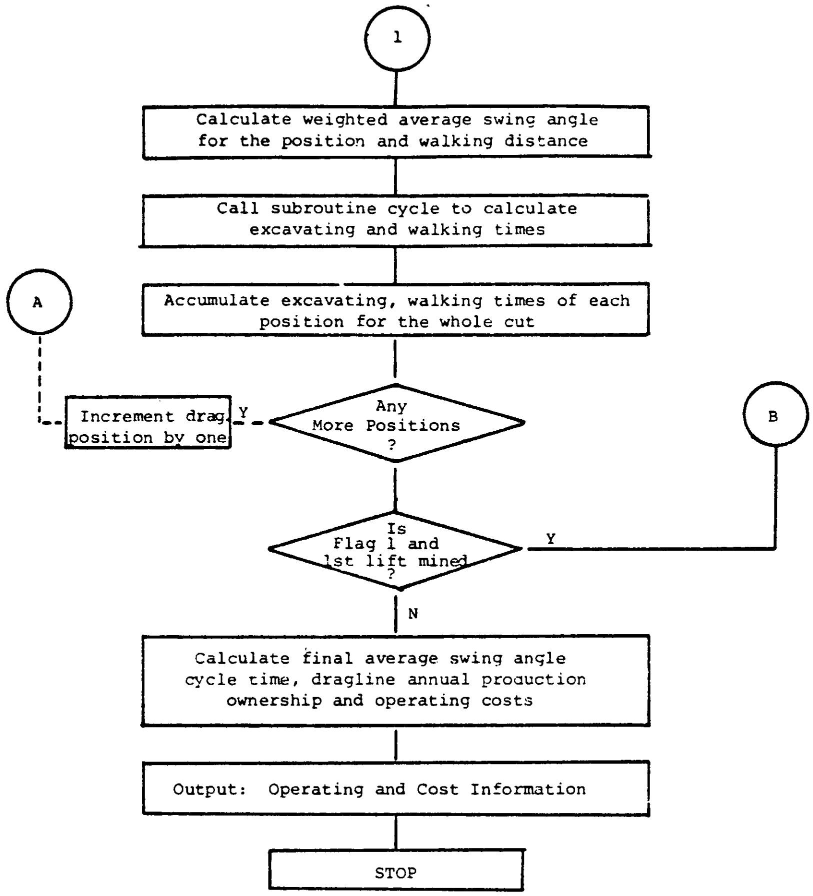


Figure 39: (Continued)

operation accordingly.

The model first determines the dragline operating radius by using the equation derived in the first section of this thesis. Final average swing angle and average cycle time calculations are identical to procedure discussed in the Side Casting Model and are based on an idealized swing time curve. Once the average cycle time is determined, the model calculates the required bucket capacity to meet predetermined production demand.

The dragline operating radius is the required horizontal distance from centroid of the tub to the point under the boom sheav. The effective spoil radius required for the physical properties can be obtained by subtracting dragline tub radius at safe distance from edge of the tub to crest from the dragline operating radius.

The method of calculation of overburden and spoil volumes for this model is identical to the side casting model. The reader may refer to the Side Casting Model for the detail discussion.

Input Data

Input data includes physical properties of the area along with operational variables such as pit width, cut segment length, idealized swing angle vs. swing time curve, and the generalized machine characteristics. In addition, cubic yard of overburden production dragline is required to removed to meet annual coal demand must also be input. The input data is read into the computer program from data file named SELECT.DAT. Sample data file is shown in Table 8.

Computer Flow Chart

The flow chart of this model is illustrated in Figure 40 .

Sample Output

For the input data presented in Table 8 , sample output is shown in Table 9 . The required dragline operating radius and bucket capacity from this output is used to select candidate dragline from various available dragline models made by different manufacturers.

Extended Bench Model

The Extended Bench model, as discussed earlier, assumes dragline reach is not sufficient to remove all the overburden and that the dragline has to extend the existing bench width to enable itself to remove the overburden clear of the coal. The portion of the material volume used to extend the bench has to be handled twice by the machine. This rehandle volume, along with the necessary cycles the dragline has to perform to extend the bench, reduces the machine's annual overburden capacity to uncover coal for a given mine productivity.

The Extended Bench Model takes into consideration the rehandle volume, and the procedure to extend the bench for calculation of the actual yearly dragline production. The model also determines the dragline's operating and ownership

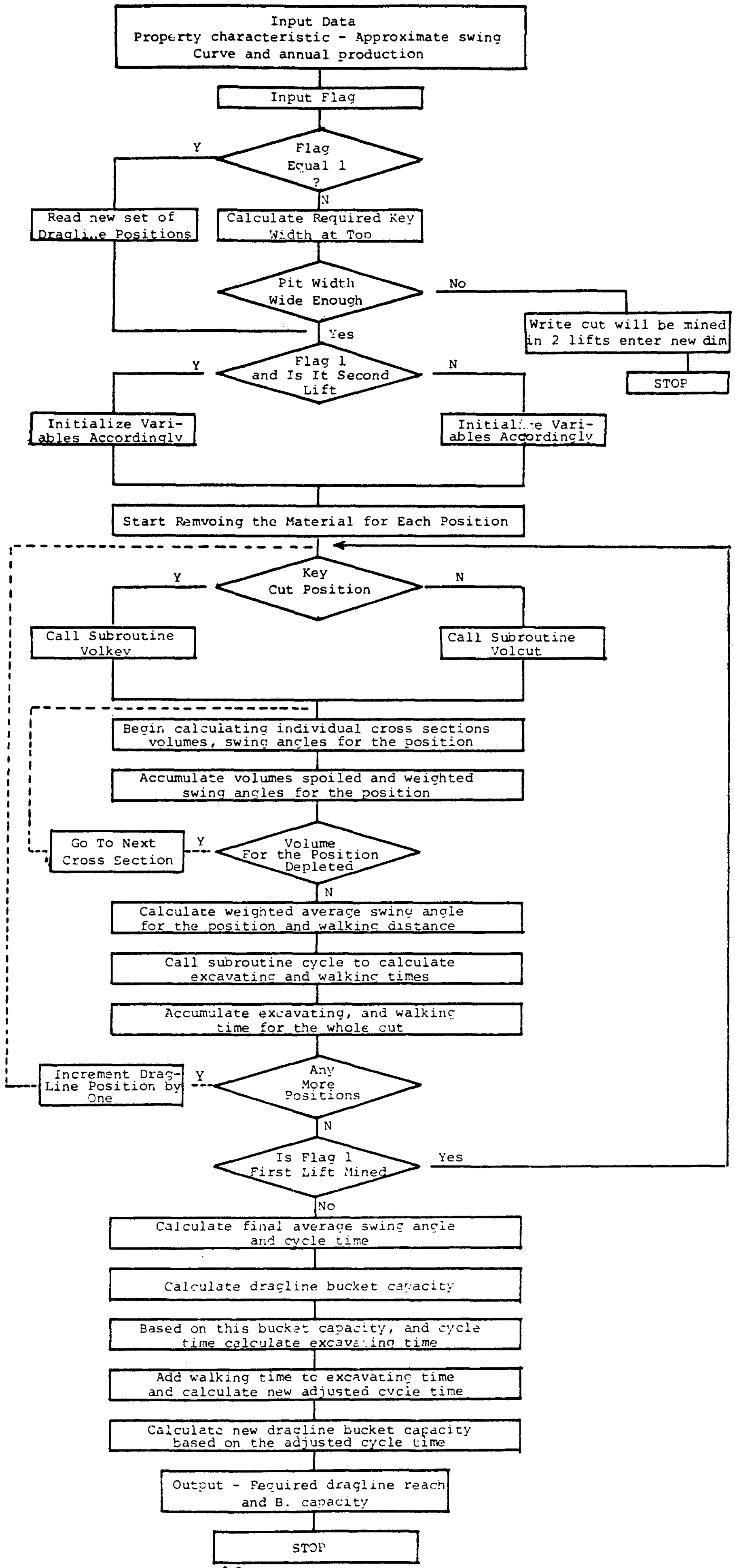


Figure 40: Computer Flow Chart
For the Dragline Selection Model

TABLE 8: SAMPLE INPUT DATA FOR DRAGLINE SELECTION MODEL

```
H, CT, A, B, C, FA, SF, X, W, FA
CABHT, CABRAD, P
DT, BPT, ST1, ST2, SCC, WS, CLT
AP, SH, AY, JF, FF
NPK, NTP, N
DDFDF(1), DDFH(1)
DDFDF(2), DDFH(2)
DDFDF(3), DDFH(3)
DDFDF(4), DDFH(4)
DDFDF(5), DDFH(5)
IFLAG
NFSIKP, NFSLKP, NFSTP
DDFDF(6), DDFH(6)
DDFDF(7), DDFH(7)
DDFDF(8), DDFH(8)
```

```
90.,5.57,63.4,35.,76.,38.,22.,100.,120.,10.
30.,30.,40.
12.,12.3,40.,46.,18.,0.25,180.
34880459.,6800.,0.88,0.85,0.95
3,5,5
80,90
60,90
40,90
40,70
40,40
1
6,6,8
40,90
40,70
40,40
```

TABLE 9: SAMPLE OUTPUT FOR THE DRAGLINE SELECTION MODEL

REQUIRED DRAGLINE REACH	:	282.42	FT
BUCKET CAPACITY	:	175.60	CU YD
AVERAGE SWING ANGLE	:	113.90	DEGREES
AVERAGE CYCLE TIME	:	71.78	SECONDS
ANNUAL PRODUCTION	:	34880459.0	BCY

FOR

OVERBURDEN HEIGHT	:	90.00	FT
COAL THICKNESS	:	5.57	FT
HIGHWALL ANGLE OF REPOSE	:	63.40	DEGREES
SPOIL ANGLE OF REPOSE	:	35.00	DEGREES
COAL ANGLE OF REPOSE	:	76.00	DEGREES
PIT WIDTH	:	120.00	FT
CUT LENGTH	:	100.00	FT

costs with respect to mine productivity.

The terms "dragline productivity" and "mine productivity" need to be defined. Dragline productivity is defined as the total material removed by a dragline for a given pit configuration into a spoil area in a unit time. Mine productivity is considered to be dragline productivity less rehandling.

The operational procedures unique to the Extended Bench Model are described in the following sections.

Overburden Removal and Digging Procedure

The Extended Bench Model includes the option of a chop down bench to remove a portion of the overburden to gain reach, thereby reducing percent rehandled. The user specifies the overburden height the dragline will chop down in the model. If a chop down bench is used, the dragline will chop down from the bench directly behind the machine. The model assigns this material to be spoiled for bench extension. Once the chop down is completed, the dragline makes the key cut and removes the remaining portion of the main cut segment. The overburden removal procedure for the Extended Bench model is illustrated in Figures 19 and 20.

When overburden height necessitates two lift cut removal, the model follows the two lift cut removal procedures as discussed in the Side Casting Model.

Dragline Positioning and Spoiling

The user defines the pattern for dragline positions for the Extended Bench Model using the procedure described in Side Casting Model.

The dragline removes all the chop down bench segment from the first position on the bench and spoils this material to extend the bench. When the extended bench cannot be completed with the chop down material, the dragline starts digging the key cut and uses this key cut material to complete the bench extension. Once the bench extension is completed, the remaining material is spoiled into the spoil area starting from an initial dumping point and continuing along the curvature of the dragline operating radius.

When the cut segment is mined in two lifts, a second set of dragline positions must be entered by the user. The main cut of the first lift may also be used along with the chop down and key material to extend the bench.

Required Volume Calculation to Extend the Bench

The equation for the amount of material required to extend the bench is derived from the cross sectional geometry of the pit as shown in Appendix B.

Before calculating the volume required for the pit extension, the model determines the necessary width to extend the bench. When a portion of the overburden is chopped down, the overburden height is adjusted to take the reach gained from chop down into consideration. The equation to adjust the overburden height for chop down is also derived in Appendix B. The model calculates the required dragline reach for the adjusted overburden height and compares this calculated reach with the actual machine reach to determine the required bench extension.

Spoil Volume Calculation

The volume of the spoil room available for a given set-up length of the overburden is calculated in the same manner as in the Side Casting Model. However, the capacity of the cross sectional area, used to calculate the spoil volume is adjusted by deducting the volume already filled by bench extension. These relationships are derived in Appendix B.

Rehandle Volume Calculation

Rehandle volume is calculated by subtracting the volume of the bench extension material in the final spoil volume from the volume required to extend the bench. Rehandle percentage is calculated by dividing rehandle volume by the product of the bank volume and swell factor.

Initial Position of the Spoil Pile

The model assumes the initial position of the spoil pile to be a cut length distance away from the center of the dragline position, which is presumably located at a safe distance away from the digging face. This initial dumping point is on a line perpendicular to the highwall and going through the center of the final dragline position in the previous cut.

Overburden Volume Calculation

Overburden volume to be removed from a given position is calculated in the general manner described in the Side Casting Model.

Some minor modifications are made to include the volume of the extended bench material in the main cut volume calculation. These modifications are:

1) Pit width is redefined to include the width of the extended bench.

2) The angle of repose for the highwall is changed to the angle of repose of the spoil.

3) The swell factor is adjusted so that swell for the rehandle volume is counted once.

Other Calculations

Final average swing angle, cycle time, and operating and ownership cost calculations follow the same procedure for the Extended Bench Model as for the Side Casting Model.

Computer Program

The program consists of a main program and five subprograms. The main program performs the following: inputs data; determines whether or not a cut will be mined in one lift or two lifts; calculates chop down overburden volume, swing angle, the cycle time and total chopping time; adjusts overburden height for chop down; determines required pit extension; controls the spoil location; calculates average swing angles for all the positions; calculates walking distances; keeps track of the volume of the cut already spoiled, cycle times and the walking times for the whole cut segment; calculates dragline yearly production; performs cost analysis for the dragline; and outputs the input data, operational characteristics and cost summary. The first subprogram calculates the volume necessary to extend the bench to the required pit width. The second subprogram calculates the volume spoiled in the spoil pit area from the bench extension. The third subprogram calculates cycle and walking times for each position and determines the time spent at each location. The fourth subprogram calculates the removable volume from each key cut position, and the fifth subprogram calculates the removable volume from each main cut position.

Input Variables

Most of the input variables for the Extended Bench Model are the same as the Side Casting Model. For a detailed description of these input variables the reader should refer to the Side Casting Model. A list of input variables along with program variables are listed in Appendix D.

Sample input data is presented in Table 10. The computer program reads the input data from the data file named EXT.DAT.

Computer Flow Chart

A computer flow chart for the Extended Bench Model is presented in Figure 41.

Sample Output of the Model

Sample output of the model is shown in Table 11.

TABLE 10: SAMPLE INPUT DATA FOR THE EXTENDED BENCH MODEL

```
H, W, CT, CD, A, B, C, FA, SF, X, WK
CDBH
MT
DR, BC, CABHT, CABRAD, P
DT, BPT, ST1, ST2, SCC, WS, CLT
SH, AV, JF, RF, FF
DIC, PCKH, PCH, LR, DOL, CRF, ITIP
NPK, NTP, N
DDFDF(1), DDFH(1)
DDFDF(2), DDFH(2)
DDFDF(3), DDFH(3)
DDFDF(4), DDFH(4)
DDFDF(5), DDFH(5)
IFLAG
NF, SIKP, NFSLKP, NFSTP
DDFDF(6), DDFH(6)
DDFDF(7), DDFH(7)
DDFDF(8), DDFH(8)
```

```
[14:18:44]
110.,120.,5.57,71.,63.4,35.,76.,34.,22.,100.,10.
0.0
MAR-8050-23A
285.5,56.,13.,21.5,40.
12.,12.3,40.,46.,18.,0.25,180.
6800.,.88,.85,.88,.95
14000000.,1650.,0.03,13.0,20.,0.0,.16
3,5,5
80.,90.
60.,90.
40.,90
40.,70.
40.,40.
1
6,6,8
40.,90.
40.,70.
40.,40.
```

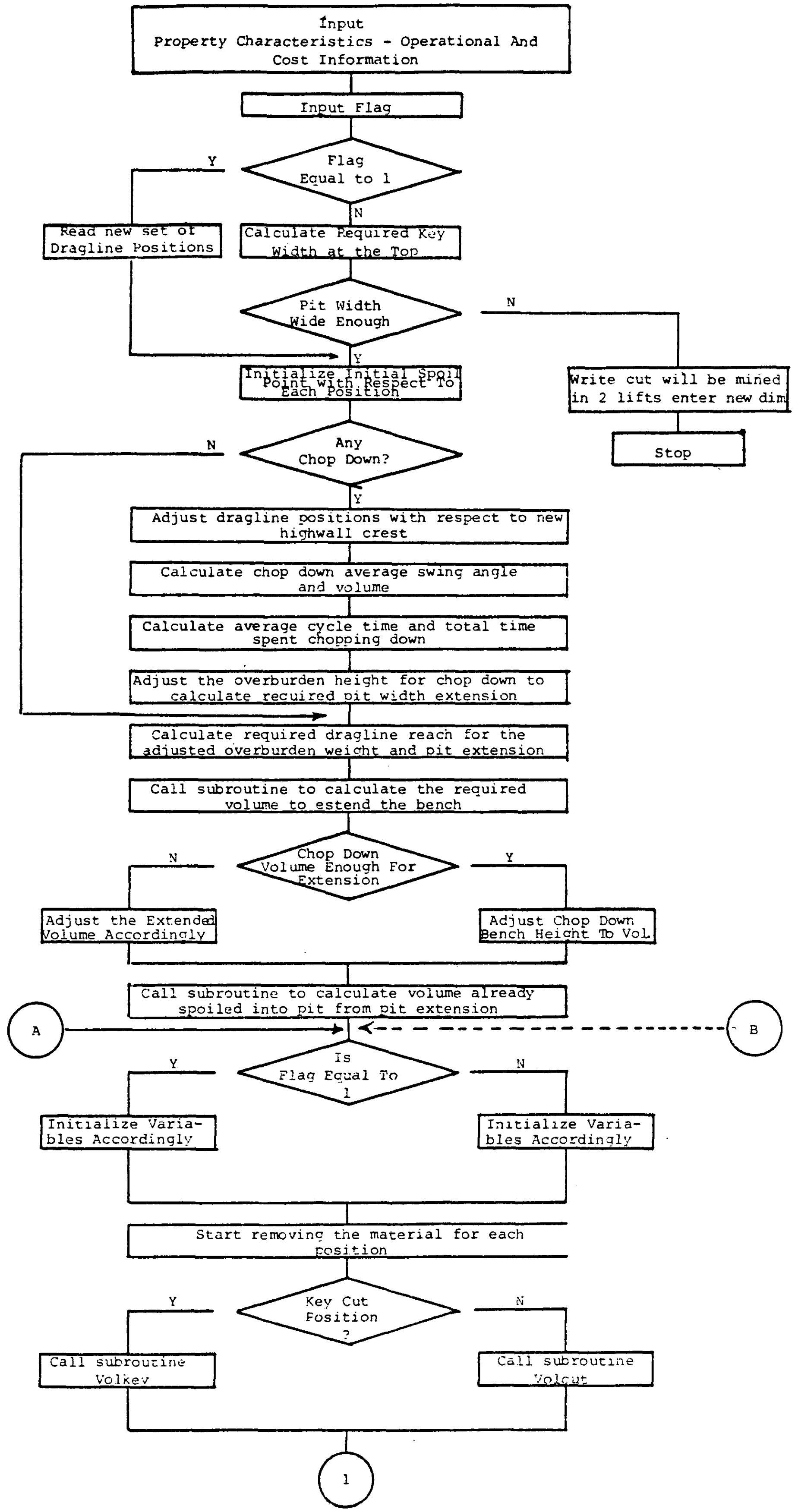


Figure 41. Computer Flow Chart For the Extended Bench Model

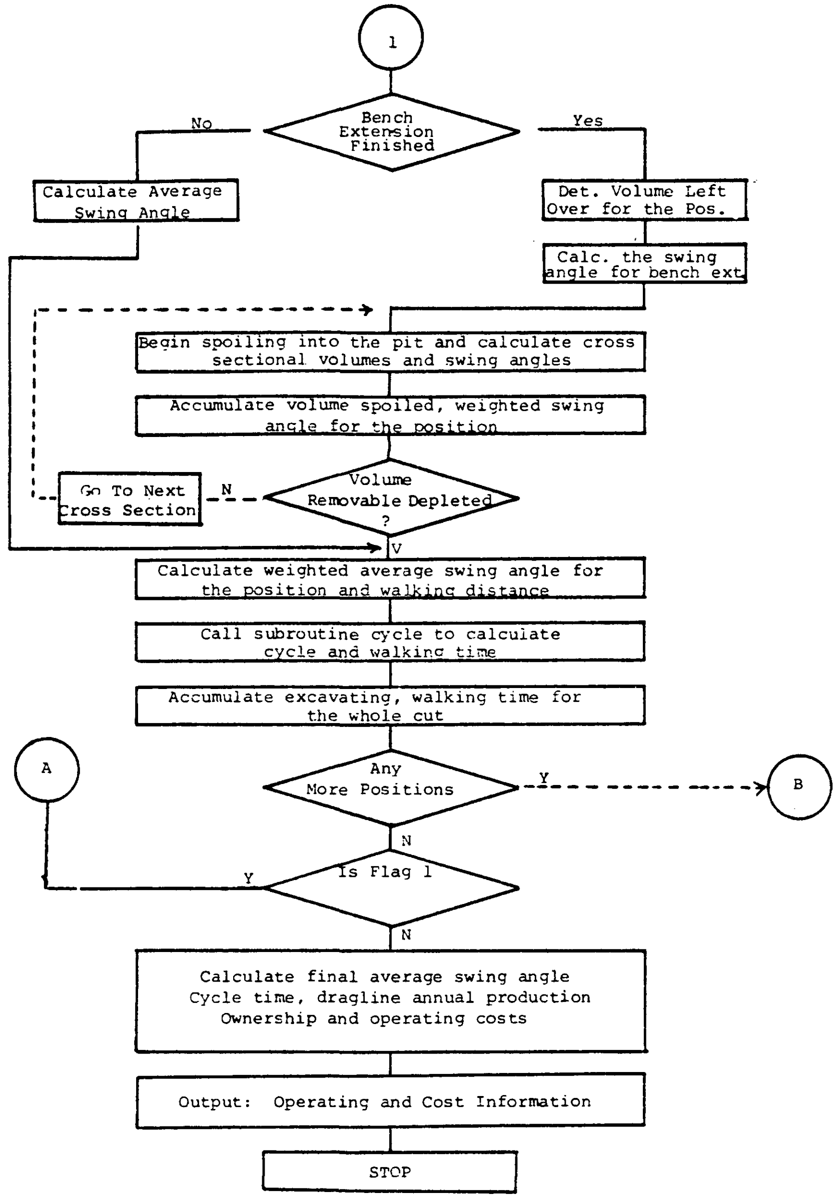


Figure 41: (Continued)

TABLE 11: SAMPLE OUTPUT FOR THE EXTENDED BENCH MODEL

PROPERTY CHARACTERISTICS

OVERBURDEN HEIGHT	:	110.0	FT
COAL THICKNESS	:	5.6	FT
HIGHWALL ANGLE	:	63.4	DEGREES
SPOIL ANGLE OF REPOSE	:	35.00	DEGREES
COAL HIGHWALL ANGLE	:	76.00	DEGREES
SWELL FACTOR	:	122.00	%
COAL RECOVERY	:	88.00	%
PIT WIDTH	:	120.00	FT
CUT LENGTH	:	100.00	FT
CHOP DOWN BENCH HEIGHT	:	0.00	FT
PIT EXTENTION	:	40.49	FT

DRAGLINE CHARACTERISTICS

DRAGLINE TYPE	:	MAR-8050-2	
DRAGLINE REACH	:	285.50	FT
BUCKET CAPACITY	:	56.00	CUBIC YARD
SCHEDULED HOURS	:	6800.00	HOURS/YEAR
MECHANICAL AVAILABILITY	:	88.00	%
JOB FACTOR	:	85.00	%

DRAGLINE PRODUCTION AND COST SUMMARY

AVERAGE SWING ANGLE	:	124.34	DEGREES
AVERAGE CYCLE TIME	:	76.18	SECONDS
PRODUCTION RATE	:	2500.40	CU. YD/HR
TOTAL VOLUME SPOILED	:	12718035.0	CU.YD/YEAR
PRODUCTION RATE (BANK)	:	2049.51	CU.YD/HR
TOTAL VOLUME SPOILED (BANK)	:	5901965.0	CU. YD/YEAR
TOTAL VOLUME CHOPPED	:	0.00	CU.YD/YEAR
TOTAL VOLUME REHANDLED	:	5517637.4	CU.YD/YEAR
PERCENT REHANDLED	:	43.38	%
PERCENT CHOP DOWN	:	0.00	%
TOTAL COAL MINED	:	252077.41	TONS
OPERATING COST	:	6.43	$/TON
	:	0.10	$/CU. YARD
OWNERSHIP COST	:	7.42	$/TON
	:	0.11	$/CU. YARD
TOTAL COST	:	13.85	$/TON
	:	0.21	$/CU.YARD

TABLE 11: (Continued)

DRAGLINE PRODUCTION SUMMARY
FOR
EACH POSITION

POSITION	1	2
VOLUME SPOILED (CU. YD)	3024.71	1386.07
AVERAGE SWING ANGLE (D)	159.80	159.20
EXCAVATING TIME (HRS)	1.73	0.80
WALKING TIME (HRS)	0.24	0.07
TOTAL TIME (HRS)	1.97	0.88
POSITION	**3**	**4**
VOLUME SPOILED (CU. YD)	2552.70	15294.75
AVERAGE SWING ANGLE (D)	157.99	162.17
EXCAVATING TIME (HRS)	1.45	5.96
WALKING TIME (HRS)	0.07	0.07
TOTAL TIME (HRS)	1.52	6.03
POSITION	**5**	**6**
VOLUME SPOILED (CU. YD)	13442.74	6963.48
AVERAGE SWING ANGLE (D)	168.31	120.13
EXCAVATING TIME (HRS)	5.32	3.59
WALKING TIME (HRS)	0.13	0.11
TOTAL TIME (HRS)	5.45	3.70
POSITION	**7**	**8**
VOLUME SPOILED (CU. YD)	15294.75	12433.62
AVERAGE SWING ANGLE (D)	75.21	73.65
EXCAVATING TIME (HRS)	4.57	3.69
WALKING TIME (HRS)	0.07	0.13
TOTAL TIME (HRS)	4.64	3.82

The Pull Back Dragline Selection Model and the Two Machine Pull Back Model.

Introduction.

When a given dragline reach is not sufficient to remove all the overburden and one machine cannot meet production requirements, it may be applicable to use two machines in tandem.

The Pull Back Machine Selection Model assumes the primary dragline is already selected for a property. Then assuming a second machine will operate from the spoil side the program sizes the second machine to keep pace with the primary machine. The Two Dragline Pull Back Model simulates the operation of these two machines working together to remove overburden, using the Pull Back method of stripping previously discussed in the first section. The model is designed to evaluate both draglines' performance in terms of annual overburden removed, and ownership and operating costs.

These two models consider dragline positions, digging and spoiling procedures and dragline walking pattern for a whole cut to determine overburden removal capacity of the primary machine. The models assume that the primary machine side casts into the spoil area enabling the second machine to "pull back" the rehandle material and uncover the coal seam. Then considering pit geometry and physical properties of the overburden, the model determines the amount of material to be pulled back and assigns this rehandle to the pull back machine. The Pull Back Dragline Selection Model determines the required bucket capacity for the pull back machine to remove primary machines rehandle output. The model also determines the operating radius required to pull back the spoil clear of the coal and sizes a dozer to prepare a working bench on the spoil for the pull back machine. The equation to determine the operating radius of the pull back machine is derived in Appendix C.

Overburden Removal and Spoiling Procedures.

The primary machine removes the overburden using the same procedure discussed in the Side Casting Model. One exception is that, in the Side Casting Model the dragline removes the overburden and gradually builds up the spoil pile along the curvature to its maximum capacity without causing any rehandle, while, the pull back model assumes that the primary dragline will remove the overburden by side casting and builds up the spoil pile by distributing the material equally along the curvature into the pit area. This assumption provides straight primary machine spoil pile peaks which the dozer must level off in preparing the pull back dragline working bench.

After the bench is prepared for the pull back machine, the model assumes the dragline works from this prepared bench and removes the excess spoil material clear of the coal and places it into an area between the previous spoil peaks. This procedure is shown in Figures 22 and 23.

Overburden and Spoil Volume Calculations

a) Primary Machine

Overburden volume to be removed from a giving position of the primary dragline is calculated by following the same procedure as discussed in the Side Casting Model. From each position, the primary dragline can only remove the amount of material determined by the digging angle. This overburden volume calculation is included in Appendix C. Since the dragline distributes the calculated volume along the cut segment long spoil area, and material can be spoiled continuously without any consideration given to whether or not it will cover the coal seam, the capacity of the spoil segment is not limited. Unlike the Side Casting Model, the spoil volume calculation is not required for the primary machine spoil pile.

b) Pull Back Machine

The model assumes that the only material the pull back machine has to remove is the excess spoil which extends over the coal seam. Calculation of the rehandle volume determines the amount of overburden to be removed by the pull back dragline. This rehandle volume calculation is explained in Appendix C. Figure 22 illustrates the spoil area to be rehandled by the pull back machine.

c) Dozer

The amount of material the dozer has to remove is the portion of the spoil peak which is to be leveled for the pull back machine working bench. The model assumes that the dozer levels this ridge in such a manner that the material from the ridge will fill the area between the peaks when it is leveled. Figure 22 shows the material to be leveled by the dozer. The calculation of the material volume the dozer must level is included in Appendix C.

Swing Angle Determination

a) The Primary Machine.

The swing angle which the primary machine must make from a given position is calculated as an average of the swing angle made to spoil the material at the initial spoiling point and the final spoiling point. (The initial spoiling point starts from a cut length distance away from the final drag-line position as discussed for the medium overburden case of Side Casting Model.) The model calculates the final average swing angle for the machine by weighing the average swing angles by the volume removed from each dragline position utilized to remove the cut segment.

b) Pull Back Machine.

The model assumes the pull back average swing angle to be 180 degrees (1,11).

Cycle Time Calculation

The cycle time calculation in both models is based on the same procedure as discussed in the side casting model.

Ownership and Operating Cost Calculation

The two machine pull back model calculates the ownership and operating costs for both draglines as discussed in the side casting model. Individual dragline cost calculations are based on their yearly production capacities. Dozer operating and ownership costs per hour are predetermined by the user and input into the computer before execution. Total cost per cubic yard includes each machine cost and it is based on the bank cubic yards removed in a given cut by the primary machine.

Computer Program

The pull back machine selection model consists of a main program and three subprograms. The main program performs the following: inputs data; determines whether or not a cut will be mined in one lift or two lifts; calculates final average swing angle and the primary dragline annual production capacity, determines reach requirements of the pull back machine; calculates the rehandle volume to be removed by the pull back machine, and determines the bucket capacity required to match the primary machine rehandle production; sizes a dozer for bench preparation; and outputs the required machine specifications for the pull back dragline and the dozer. The first subprogram calculates cycle and walking times for each position of the primary machine and determines the time spent at each location.

The second subprogram calculates the removable volume for each key cut position, and the third subprogram calculates the removable volume for each main cut position.

The two machine pull back simulation model also consists of a main program and three subprograms. The main program assumes that both draglines and a dozer have already been sized and performs the following: inputs data; determines whether or not a cut will be mined in one lift or two lifts; calculates the final primary machine average swing angle, and walking distances; determines primary and pull back machine's annual outputs; calculates the individual machine's ownership and operating costs, and the total cost of all the machines per ton of coal recovered. The three subprograms are identical to the ones discussed in the pull back dragline selection model.

Description of Program Variables

Most of the input and program variables are identical to the variables discussed on the side casting model. The variables unique to the pull back dragline selection model and two machine pull back model are described in Appendix D.

Input Data

Dragline selection model reads the input data from data files named PUL 1. DATA and the two machine pull back model reads the input data from the data file PUL 2. DAT. Sample data files are shown in Tables 12 and 13.

TABLE 12: INPUT DATA FOR PULL BACK DRAGLINE SELECTION MODEL

```
H, CT, CD, A, B, C, SF, X, W, WK
MT
DR, BC, CABHT, CABRAD, P
NPK, NTP, N
DDFDF(1), DDFH(1)
DDFDF(2), DDFH(2)
DDFDF(3), DDFH(3)
DDFDF(4), DDFH(4)
DDFDF(5), DDFH(5)
DT, BPT, ST1, ST2, SCC, WS, CLT
SH, AY, JF, RF, FF
IFLAG
NFSIKP, NFSLKP, NFSTP
DDFDF(6), DDFH(6)
DDFDF(7), DDFH(7)
DDFDF(8), DDFH(8)
```

```
140.,10.,80.,68.,38.,85.,20.,100.,120.,10.
BE 1570
240.,60.,30.,30.,40.
3,5,5
80.,80.
60.,80.
40.,80.
40.,50.
40.,40.
12.,3.,40.,46.,18.,0.25,180.
6800.,.8,0.8,.9,0.9
1
6,6,8
40.,60.
40.,50.
40.,40.
```

TABLE 13: INPUT DATA FOR THE TWO MACHINE PULL BACK SIMULATION MODEL

```
H, CT, CD, A, B, C, SF, X, W, WK, RF
MT1
DR, BC, FF, CABHT, CABRAD, P
NPK, NTP, N
DDFDF(1), DDFH(1)
DDFDF(2), DDFH(2)
DDFDF(3), DDFH(3)
DDFDF(4), DDFH(4)
DDFDF(5), DDFH(5)
DT, BPT, ST1, ST2, SCC, WS, CLT
SH(1), AV(1), JF(1)
SH(2), AV(2), JF(2)
MT2
PBDR, PBBC, PBFF
PBDT, PBBPT, PBST1, PBST2, PBSCC, PBWS, PBCLT
PCH(1), PCKH(1), MCPCY(1), LR(1), DIC(1), COL(1), ITIP(1)
PCH(2), PCKH(2), MCPCY(2), LR(2), DIC(2), COL(2), ITIP(2)
DOCPH, DOWCPH
IFLAG
NFSIKP, NFSLKP, NFSTP
DDFDF(6), DDFH(6)
DDFDF(7), DDFH(7)
DDFDF(8), DDFH(8)
```

```
140.,10.,80.,68.,38.,85.,20.,100.,120.,10.,.9
BE 1570
240.,60.,0.9,30.,30.,40.
3,5,5
80.,80.
60.,80.
40.,80.
40.,60.
40.,40.
12.,3.,40.,46.,18.,0.25,180.
6800.,.80,.80
6800.,.80,.80
BE 850
210.,15.,0.9
12.,3.,40.,46.,18.,0.25,180.
2800.,0.07,0.06,10.,20000000.,20.,0.15
2000.,0.07,0.06,10.,10000000.,20.,0.15
35.,25.
1
6,6,8
40.,60.
40.,50.
40.,40.
```

Program Flow Charts

The flow chart for both models are presented in Figures 42 and 43.

Sample Output of the Models

Sample outputs of the pull back selection model and the two machine pull back model are presented in Table 14 and 15 respectively.

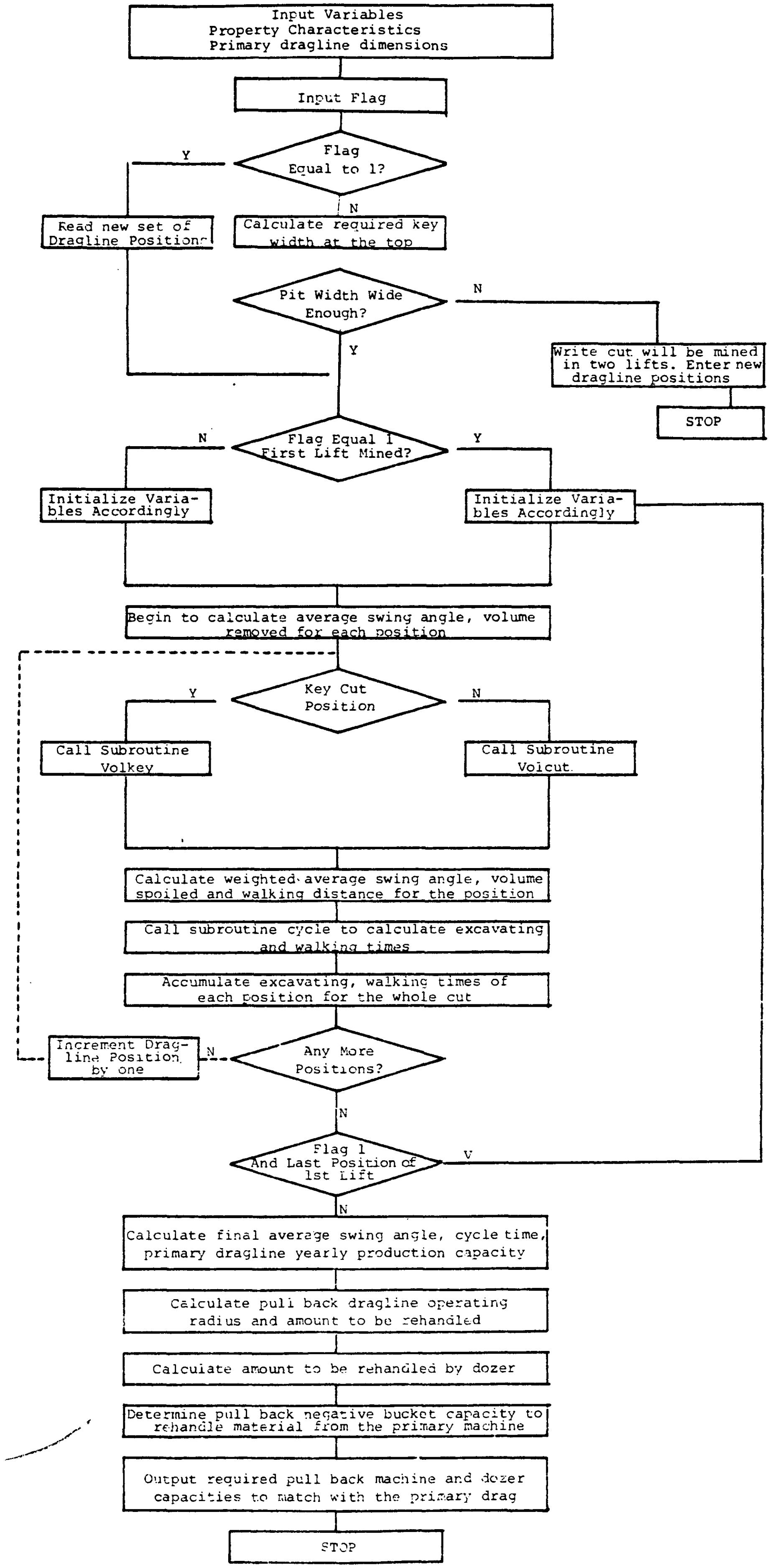


Figure 42: Computer Flow Chart For the Pull Back Machine Selection Model

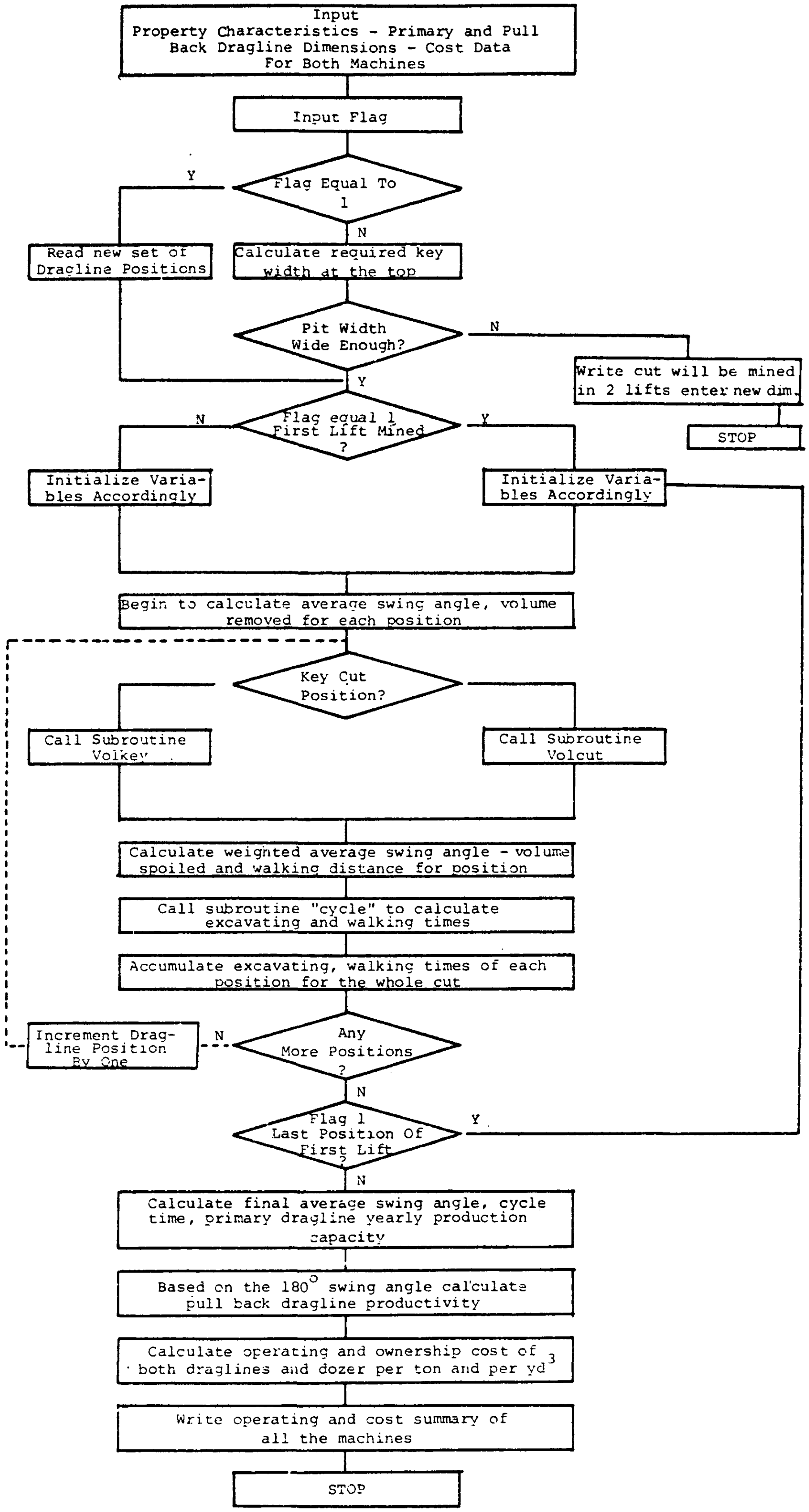


Figure 43: Computer Flow Chart
For the Two Machine Pull Back Model

TABLE 14: SAMPLE OUTPUT FOR PULLBACK DRAGLINE SELECTION MODEL

```
REQUIRED MACHINE SPECIFICATIONS
             FOR
       PULL BACK MACHINE

 REQUIRED REACH     :    254.42  FT

 BUCKET CAPACITY    :     28.01  CUBIC YARD

 DOZER PRODUCTION   :    250.93  CUBIC YARD

 PULL BACK MACHINE % REHANDLE ;     45.71

 DOZER % REHANDLE   :      7.88
```

TABLE 15: SAMPLE OUTPUT FOR TWO MACHINE PULL BACK SIMULATION MODEL

PROPERTY CHARACTERISTICS

OVERBURDEN HEIGHT	:	140.00	FT
COAL THICKNESS	:	10.00	FT
HIGH WALL ANGLE	:	68.00	DEGREES
SPOIL ANGLE OF REPOSE	:	38.00	DEGREES
COAL HIGHWALL ANGLE	:	85.00	DEGREES
SWELL FACTOR	:	1.20	%
COAL RECOVERY	:	0.90	%
PIT WIDTH	:	120.00	FT
CUT LENGTH	:	100.00	FT

MACHINE CHARACTERISTICS

DRAGLINE 1

DRAGLINE TYPE	:	BE 1570	
DRAGLINE REACH	:	240.00	FT
BUCKET CAPACITY	:	1458.00	CUBIC YD
SCHEDULED HOURS	:	6800.00	HOURS
MECHANICAL AVAILABILITY	:	0.80	%
JOB FACTOR	:	0.80	%
AVERAGE SWING ANGLE	:	76.54	DEGREES
AVERAGE CYCLE TIME	:	60.18	SECONDS
PRODUCTION RATE	:	3186.00	CU. YD/HR
TOTAL VOLUME SPOILED	:	13865472.0	CUBIC YD
COST	:	0.25	$/CUBIC YD

DRAGLINE 2

DRAGLINE TYPE	:	BE 850	
DRAGLINE REACH	:	210.00	FT
BUCKET CAPACITY	:	364.50	CUBIC YD
SCHEDULED HOURS	:	6800.00	HOURS
MECHANICAL AVAILABILITY	:	0.80	%
JOB FACTOR	:	0.80	%
AVERAGE SWING ANGLE	:	180.00	DEGREES
AVERAGE CYCLE TIME	:	69.00	SECONDS
PRODUCTION RATE	:	3055104.00	CU. YD/HR
TOTAL VOLUME SPOILED	:		
COST	:	0.57	$/CUBIC YD

TABLE 15: (Continued)

PRODUCTION SUMMARY

TOTAL COAL MINED	:	962659.91	TON/YEAR
PERCENT REHANDLE			
PULL BACK MACHINE	:	0.46	%
DOZER	:	0.08	%
TOTAL COST	:	8.87	$/CU. YD
	:	0.32	$/TON

APPLICATION OF THE MODELS

Use of the models is demonstrated by a case study involving dragline selection for a lignite property in Texas.

Case Study

The property will require 2.5 million tons per year delivered to a nearby power plant. Overburden in the property ranges from 20 to 140 ft. and consists of unconsolidated and poorly consolidated sandstones and shales. The property will be mined using conventional area methods with the exception of a 10 ft. spoil side ditch which will be left for pit drainage. In place reserve data was summarized by overburden increment (e.g., 20-40 ft., 40-60 ft., etc.). Property characteristics are presented in Appendix E.

Approach

Dragline selection for the property can be made using the following procedure:

1. Run the dragline selection model to determine a range for the dragline reach and the bucket capacity based on average overburden thickness.

2. Select number of dragline models close to the range previously determined.

3. Run models for each overburden increment represented by the mid-point of the increment (e.g., 30 ft., 50 ft., etc.) at various pit widths.

4. Combine results based on percent reserve for the overburden increment.

5. Select the machine which produces the lowest cost/ton lignite and meets the production requirements.

Results

To illustrate this procedure, first the dragline selection model was run for 90 ft. overburden height and 120 ft. pit width. The following output shows the approximate required dragline reach and the bucket capacity.

```
REQUIRED DRAGLINE REACH :     282.42  FT
BUCKET CAPACITY         :     175.60  CU YD
AVERAGE SWING ANGLE     :     113.90  DEGREES
AVERAGE CYCLE TIME      :      71.78  SECONDS
ANNUAL PRODUCTION       :34880459.0   BCY

                    FOR

OVERBURDEN HEIGHT       :      90.00  FT
COAL THICKNESS          :       5.57  FT
HIGHWALL ANGLE OF REPOSE:      63.40  DEGREES
SPOIL ANGLE OF REPOSE   :      35.00  DEGREES
COAL ANGLE OF REPOSE    :      76.00  DEGREES
PIT WIDTH               :     120.00  FT
CUT LENGTH              :     100.00  FT
```

Based on this result, four Marion dragline models are considered to be the candidate draglines. The characteristics of these machines are shown on Table 16. The side casting and extended bench simulation models were run for 100, 120, 140, 160, 180 and 200 ft. pit widths for each dragline model. The results

TABLE 16. LIST OF DRAGLINES USED FOR THE CASE STUDY

MAR-8200-12A	
Dragline Operating Radius	292 Feet
Bucket Capacity	72 Cubic Yards
Capital Cost	16,075,500 Dollars
Power Consumption	2300 KWH/HR
MAR-8200-21R	
Dragline Operating Radius	310.0 Feet
Bucket Capacity	67.0 Cubic Yards
Capital Cost	16,075,500 Dollars
Power Consumption	2,100.0 KWH/HR
MAR-8050-23A	
Dragline Operating Radius	295 Feet
Bucket Capacity	56 Cubic Yards
Capital Cost	14,000,000 Dollars
Power Consumption	1650 KWH/HR
MAR-8750-28A	
Dragline Operating Radius	340.0 Feet
Bucket Capacity	80.0 Cubic Yards
Capital Cost	27,084,000 Dollars
Power Consumption	2,800.0 KWH/HR

obtained from the computer output of the models are tabulated in Appendix E. From this data, the weighted average annual coal production, the dragline hourly production and cost per ton of lignite are extracted and summarized in Table 17.

The data (Table 17) shows some interesting trends. Production in BCY/Scheduled Hour and lignite production increases with pit width up to 160 ft. as the cost/ton lignite decreases. For pit widths greater than 160 ft., the opposite is true. The increase in production with increasing pit width to 160 ft. is probably caused by a number of factors:

1. Less productive key cut is a smaller percentage of total material moved.

2. Material per position increases, reducing the percent walking time for the set-up.

3. Decrease in percent rehandle in high overburden where extended bench with chop down was employed.

The data in Appendix E shows that for pit widths greater than 160 ft., the less productive extended bench method is used at one increment lower overburden height. This factor causes the production decrease for pit widths greater than 160 ft.

Based on minimum cost/ton lignite criteria, 160 ft. pit width would be selected. For this pit width, the annual coal production and the total cost for all the dragline models considered are listed on the next page.

TABLE 17: DRAGLINE COMPARISONS FOR VARIOUS PIT WIDTHS

PIT WIDTH (FT.)	DRAGLINE TYPES: MARION 8200-12A			MARION 8200-21R		
	ANNUAL COAL PRODUCTION (1000 T/YR)	TOTAL COST ($/TON LIGNITE)	HOURLY OVERBURDEN REMOVAL (BCY/HR)	ANNUAL COAL PRODUCTION (1000 T/YR)	TOTAL COST ($/TON LIGNITE)	HOURLY OVERBURDEN REMOVAL (BCY/HR)
100	1081	5.97	2767	1033	5.84	2615
120	1112	5.61	2820	1058	5.54	2666
140	1131	5.37	2357	1080	5.36	2706
160	1144	5.33	2887	1088	5.23	2731
180	1114	5.37	2865	1070	5.40	2706
200	1082	5.97	2828	1047	5.69	2679

TABLE 17: (Continued)

DRAGLINE TYPES

PIT WIDTH (FT.)	MARION 8050-23A ANNUAL COAL PRODUCTION (1000 T/YR)	MARION 8050-23A TOTAL COST ($/TON LIGNITE)	MARION 8050-23A HOURLY OVERBURDEN REMOVAL (BCY/HR)	MARION 8750-28A ANNUAL COAL PRODUCTION (1000 T/YR)	MARION 8750-28A TOTAL COST ($/TON LIGNITE)	MARION 8750-28A HOURLY OVERBURDEN REMOVAL (BCY/HR)
100	868	6.22	2201	1281	6.08	3201
120	891	5.87	2234	1319	5.85	3285
140	900	5.66	2274	1331	5.75	3311
160	903	5.51	2284	1337	6.05	3358
180	860	5.77	2248	1350	5.97	3398
200	835	5.73	2198	1327	5.91	3367

Dragline Model	Annual Lignite Production	Cost $/Ton
Marion 8200-12A	1,114,000	5.33
Marion 8200-21R	1,088,000	5.23
Marion 8050-23A	903,000	5.51
Marion 8750-28A	1,337,000	6.05

As seen from this listing, a minimum of three draglines will be required to meet the annual coal production for all models except the Marion 8750-28A. The last model would provide enough production with two machines.

When the suggested number of draglines are utilized, actual output by the machines will be in excess of the annual requirement. Therefore, the selected draglines might be scheduled to operate less than their full capacity. Based on this assumption, dragline ownership costs/ton are adjusted for the total production of 2.5 million for all the models. Assuming that operating cost/ton lignite is constant, total cost/ton lignite for 2.5 million tons per year production is obtained by adding adjusted ownership cost to the operating costs. Results are tabulated on Table 18.

The cost data in this table shows the Marion 8050-23A to be the optimal machine. Although this analysis is based on 2.5 million tons and shows that the Marion 8050-23A is the most optimal machine, data in Table 17 shows the Marion 8200-21R is the lowest cost dragline based on the actual machine production. Based on this analysis, it would be up to the management to decide on the final dragline selection. If the future production is to be no more

TABLE 18. FINAL COST COMPARISON FOR 2.5 MILLION TONS OF LIGNITE FOR 160 FT. PIT WIDTH

Machine Type	Number of Machines	Production Capability (1000 tons)	Production Requirement (1000 tons)	Operating Cost $/Ton	Adjusted Ownership Cost $/Ton	Total Cost $/Ton
Marion 8200-12A	3	3,342	2,500	2.42	3.89	6.31
Marion 8200-21R	3	3,264	2,500	2.35	3.76	6.11
Marion 8050-23A	3	2,709	2,500	2.45	3.32	5.77
Marion 8750-28A	2	2,674	2,500	2.23	4.08	6.31

than 2.5 million tons, the Marion 8050-23A would be the dragline for this property. If the management considers the excess production might come in handy in future years, then the Marion 8200-21R would be selected.

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

The computer programs developed in this thesis may effectively be used as a planning tool to select the correct dragline for a single, flat lying coal property and to determine the optimum strip mining method among the alternative methods discussed. These models can also be used as an aid to mining engineers and management to ascertain the effects of proposed changes in dragline operating procedures on the machine's output and operating costs with a view toward improving productivity and cost effectiveness.

Recommendations for further research include:

1) Additional field study to refine assumptions affecting chopdown and key cut productivity.

2) Use of models to determine optimum dragline productivity considering combinations of dragline positioning, pit width and set-up length. Results should be field tested.

3) Use of the extended bench model to determine optimum operating procedure from machine production standpoint.

4) Refinement of the pull-back model to include alternative pullback methods.

5) Expand the model to allow more efficient use in regard to machine selection by reducing manual steps required.

6) Include hoist function in dragline simulator.

7) Develop similar simulation techniques for:

    1) One Dragline Operation

        a) Single Dipping Seam

        b) Multiple Seams

            i) Flat Lying

            ii) Dipping

    2) Multiple Dragline Operations

        a) Single Seam Deposit

            i) Flat Lying

            ii) Dipping Seam

        b) Multiple Seams

            i) Flat Lying Seams

            ii) Dipping Seams

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APPENDIX A

Calculation of Key Cut and Prime Cut Volumes

With Respect to Dragline Positions

(After Chatterjee)

Key Cut Volumes

Referring to Figure 44, the volume calculations can be divided into three cases, depending on the position of XINT. (Assume a point 0 as the origin of reference.)

Let	DLDIST	=	Dragline distance from brow
	THTAN	=	Tangent of the maximum free angle
	DIGTAN	=	Tangent of the digging angle
	CABHT	=	Height of cab
	CABRAD	=	Radius of cab
	CUT	=	Cut length
	XINT	=	Co-ordinate of point of intersection
	XBROW	=	Co-ordinate

The co-ordinate XINT must first be calculated.

DLDIST (DF) = OF - OA - AB

= X(1) - CUT - DPETH/THTAN

DIGTAN = Tan (Angle GDE)

= EG/DE

= EG/(DF - EF)

= CABHT / (DLDIST - CABRAD)

$$\text{XINT} = \text{OE} - (\text{BD} + \text{EG}) / \text{DIGTAN}$$

$$= \text{X(1)} - \text{CABRAD} - (\text{DEPTH} + \text{CABHT}) / \text{DIGTAN}$$

Depending on the value of XINT, the volumes are calculated as follows:

CASE (1): XINT $<$ 0

Referring to Figure 45:

Total Volume = Volume (1) + Volume (2)

Volume (1) = CUT * Average Area

UHT = CUT * DIGTAN

LHT = DEPTH - UHT

MIDKEY = BOTKEY + (LHT/DEPTH) * (TOPKEY - BOTKEY))

$\therefore$ Volume (1) = CUT * UHT * (TOPKEY + MIDKEY) /4

Volume (2) = Average length * Average area

C = -XINT * DIGTAN

BXLONG = DEPTH/THTAN - OX

Now at point P,

OX * THTAN = OX * DIGTAN + C

So BXLONG = DEPTH/THTAN - c/(THTAN - DIGTAN)

$\therefore$ Volume (2) = BXLONG * UHT * (TOPKEY + MIDKEY) /4

$\therefore$ TOTAL VOLUME = (BXLONG + CUT) * UHT * (TOPKEY + MIDKEY) /4

CASE (2): $0 < XINT < OJ$

Referring to Figure 46:

Total Volume = Volume (1) + Volume (2+3) - Volume (3)

The values of UHT, LHT and MIDKEY are determined by the same calculations as for case (1).

As previously,

```
Volume (1)   = CUT * UHT * (TOPKEY + MIDKEY) /4
Volume (2+3) = OJ * DEPTH * (TOPKEY + BOTKEY) /4
Now OJ       = DEPTH/THTAN

I.E. VOLUME (2+3) = DEPTH **2* (TOPKEY + BOTKEY)/(4*THTAN)
     VOLUME (3)   = (OJ - XINT) * LHT * (BOTKEY + MIDKEY) /4
                  = (XBROW - XINT) * LHT * (BOTKEY + MIDKEY) /4

     TOTAL VOLUME = CUT * UHT (TOPKEY + MIDKEY) /4
                  + DEPTH **2* (TOPKEY + BOTKEY)/(4*THTAN)
                  - (XBROW - XINT) * LHT * (BOTKEY + MIDKEY) /4
```

CASE 3: $XINT > OJ$

Referring to Figure 47:

Total Volume = Volume (1) + Volume (2) + Volume (3)

Area = area of cross-section of key-cut

= DEPTH * (TOPKEY + BOTKEY)/2

Volume (1) = LD * Average area

= (OJ + CD - XINT) * AREA /2

= (XBROW + CUT - XINT) * AREA/2

Volume (2) = CL * Area

= (XINT - XBROW) * AREA

Volume (3) = OJ * Average area

= XBROW * AREA/2

$\therefore$ TOTAL VOLUME = (XBROW + CUT - XINT) * AREA/2

+ (XINT - XBROW) * AREA

+ XBROW * AREA/2

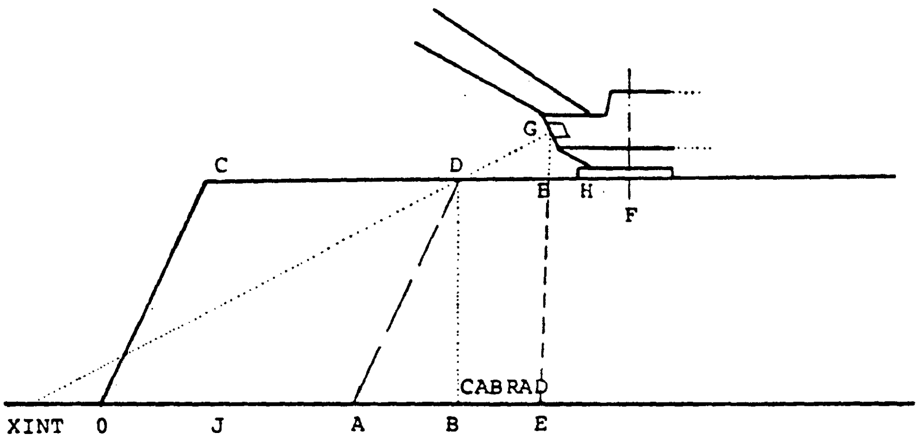

Figure 44: Dragline Digging Angle

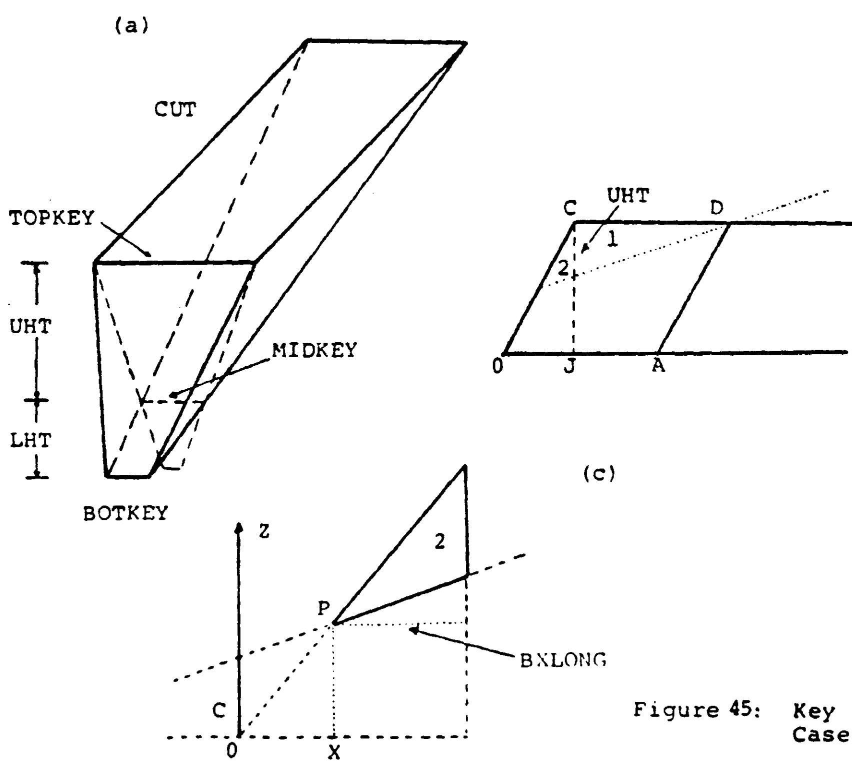

Figure 45: Key Cut Volume - Case (1).

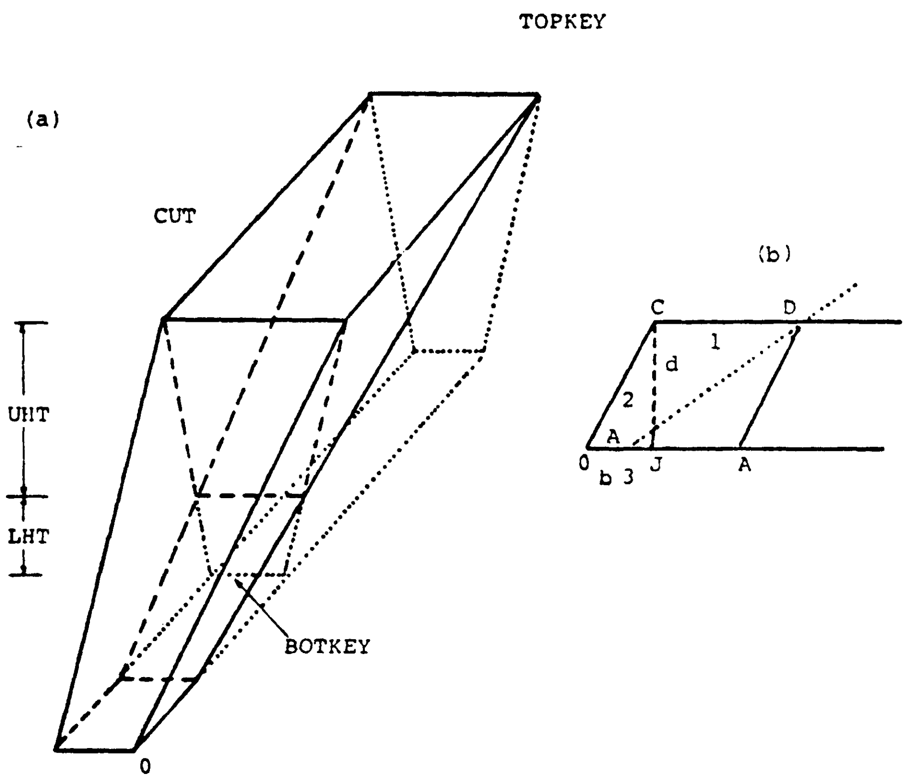

Figure 46: Key Cut Volume - Case (2)

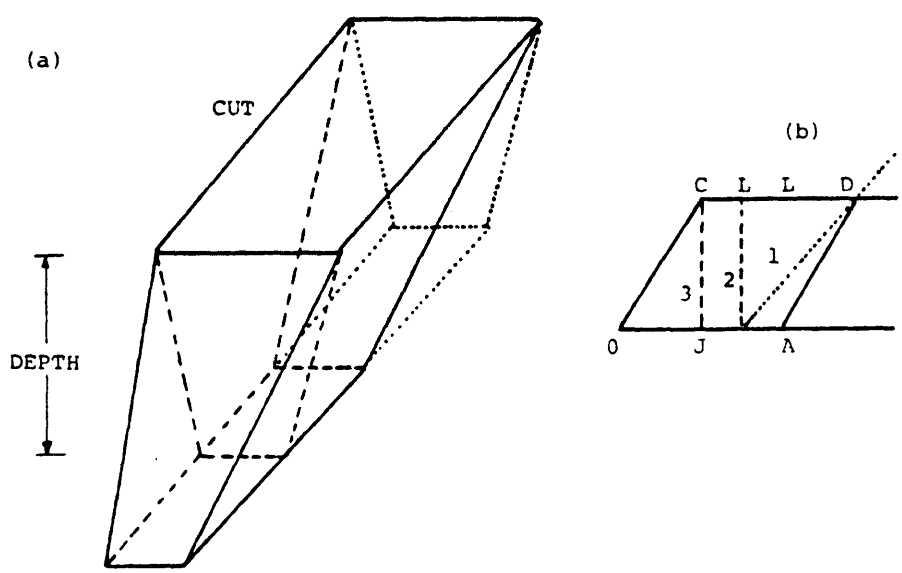

Figure 47: Key-cut Volume - Case (3)

Prime Cut Volumes

As shown in Figure 48, the prime cut consists of three zones:

(1) Section from high-wall brow to key cut brow.

(2) Triangular section at key cut.

(3) Triangular section at high-wall.

Zone 1:

In estimating the volumes for this zone, the cross-sectional areas of the cut are evaluated from diagrams 45 to 47 depending on the particular case involved. The volume is given by the product of this area and the width which is to be dug.

As for the key cut, three cases apply in the calculations, depending on the digging angle.

Case 1: Area (1) = UHT * CD/2

= UHT * CD/2

Area (2) = UHT * BXLONG/2

$\therefore$ TOTAL AREA = UHT * (BXLONG + CUT)

Case (2): Area (1) = UHT * CUT/2

Area (2+3) = DEPTH * OJ/2

= DEPTH * (XBROW - XFBOT) /2

where XFBOT = 0

Area (3) = LHT * (OJ - XINT)/2

= (DEPTH - UHT) * (XBROW - XINT)/2

∴ Total Area = UHT * CUT/2 + DEPTH * (XBROW - FBOT)/2

- (DEPTH - UHT) * (XBROW - XINT)/2

Case 3: Area (1) = DEPTH * LD/2

= DEPTH * (OJ + CD - XINT)/2

= DEPTH * (XBROW + CUT - XINT)/2

Area (2) = DEPTH * CL

= DEPTH * (XINT - XBROW)

Area (3) = DEPTH * OJ/2

= DEPTH * (XBROW - XFBOT)/2

where XFBOT = 0

∴ Total Area = DEPTH * ((XBROW + CUT - XINT)/2

+ (XINT - XBROW)

+ (XBROW - XFBOT)/2)

Zone 2:

The triangular section in Figure 48 contributes to the total volume excavated. The volume is calculated for this element by taking a section perpendicular to the strip direction, and not parallel to it, as for zone (1).

Let XSIDE = Cross-sectional area of triangular segment.

Case (1): Referring to Figure 48,

XSIDE = UHT * L /2

Now L = L & UHT/DEPTH

and L = TOPKEY - BOTKEY - D

= TOPKEY - BOTKEY - DEPTH/TAN (A)

i.e.L^1 = UHT * (TOPKEY - BOTKEY - DEPTH/TAN (A))/DEPTH (A)

.˙. XSIDE = UHT **2* (TOPKEY - BOTKEY - DEPTH/TAN (A))/(2*DEPTH)

From Figure 45:

Total Volume = STEEP

= XSIDE * (CUT + BXLONG)/2

Case (2): Referring to Figure 46:

Total Volume = Volume (1) + Volume (2+3) - Volume (3)

As for Case (1),

XSIDE = UHT **2* (TOPKEY - BOTKEY - DEPTH/TAN (A))/
(2*DEPTH)

Volume (1) = XSIDE * CUT/2

Volume (2+3) = TXSIDE * OJ/2
= TXSIDE * (XBROW - XFBOT)/2

Volume (3) = (TXSIDE - XSIDE) * (XBROW - XINT)/2

∴ Total Volume = STEEP
= XSIDE * CUT/2 + TXSIDE * (XBROW - XFBOT)/2 -
(TXSIDE - XSIDE) * (XBROW - XINT)/2

<u>Case (3)</u>: Referring to Figure 47:

Total Volume = Volume (1) + Volume (2) + Volume (3)

From Figure 48:

XSIDE = DEPTH * L/2
= DEPTH * (TOPKEY - BOTKEY - DEPTH/TAN (A))/

Volume (1) = XSIDE * LD/2
= XSIDE * (XBROW + CUT - XINT)/2

Volume (2) = XSIDE * CL

= XSIDE * (XINT - XBROW)

Volume (3) = XSIDE * OJ/2

= XSIDE * (XBROW - XFBOT)/2

$\therefore$ Total Volume = XSIDE * ((XBROW + CUT - XINT)/2 + (XINT - XBROW) + (XBROW - XFBOT)/2)

Zone 3:

The principles involved in the calculation of volumes in this zone are basically the same as those for zone 2.

Case (1): Referring to Figure 50:

XSIDE = UHT * L'/2

Now L' = UHT/TAN (HWBAT)

$\therefore$ XSIDE = UHT ** 2/(2* TAN (A))

From Figure 45:

Total Volume = SIDEVOL

= XSIDE * (CUT + BXLONG)/2

Case (2): Referring to Figure 46:

Total Volume = Volume (1) + Volume (2+3) - Volume (3)

As for Case (1),

XSIDE = UHT **2/ (2 * TAN (A))

TXSIDE = Area of whole trangle

= DEPTH * L/2

Now L = DEPTH/TAN (A)

$\therefore$ TXSIDE = DEPTH **2/(2*TAN (A))

Volume (1) = XSIDE * CUT/2

Volume (2+3) = TXSIDE * OJ/2

= TXSIDE * (XBROW - XFBOT)/2

Volume (3) = (TXSIDE - XSIDE) * (XBROW - XINT)/2

Total Volume = SIDEVOL

= XSIDE * CUT/2 + TXSIDE * (XBROW - XFBOT)/2

- (TXSIDE - XSIDE) * (XBROW - XINT)/2

Case 3: Referring to Figure 47:

Total Volume = Volume (1) + Volume (2) + Volume (3)

From Figure 50:

```
               XSIDE   = DEPTH * L/2
                       = DEPTH **2/ (2 * TAN (A))

Volume (1)             = XSIDE * LD/2
                       = XSIDE * (XBROW + CUT - XINT)/2

Volume (2)             = XSIDE * CL
                       = XSIDE * (XINT - XBROW)

Volume (3)             = XSIDE * OJ/2
                       = XSIDE * (XBROW - XFBOT)/2

Total Volume           = SIDEVOL
                       = XSIDE * ((XBROW + CUT - XINT)/2 + (XINT -
                         XBROW) + (XBROW - XFBOT)/2)
```

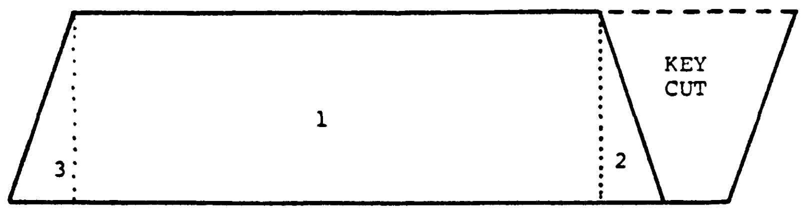

Figure 48: Strip Cross-Section.

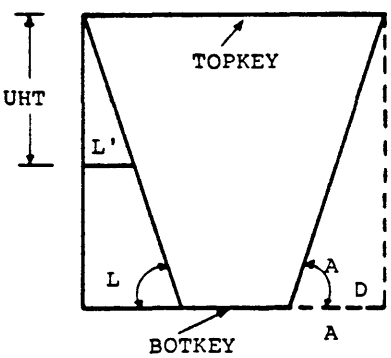

Figure 49: Section at Key Cut

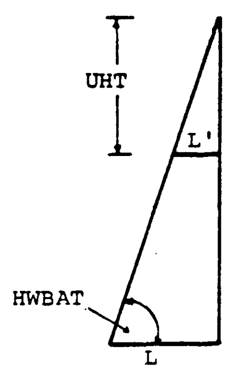

Figure 50: Section at High-Wall

APPENDIX B

Extended Volume Calculation

Calculation of Volumes Already Spoiled in Pit Area

Determination of Necessary Overburden

EXTENDED VOLUME CALCULATION

There are two different cases to calculate the extended bench volumes. The first case is illustrated in Figure 51 and it assumes the toe of the extended width will fall into the spoil width area.

The second case is illustrated in Figure 52 and it assumes the toe of the extended width will fall beyond the spoil width area.

Referring to Figure 51 and 52 derivation of the volume equations are as follows:

From the variables given below

AG = EW = Extended Width

AE = H = Depth of the overburden

OP = W = Pit Width

ED = CT = Coal Thickness

A = Angle of Repose for Highwall

B = Angle of Repose for Spoil

C = Angle of Repose for Cost

Extended areas for both cases will be calculated to obtain the extended volume, extended area should be multiplied by the cut length.

CASE 1

Referring to Figure 51 extended are AGCO is equal to:

EA(AGCO) = Area ABCD-AREA GBC-AREA AEF-AREA EFOD.

AD = H+CT

EF = H/TanD(A)

BC = AD

GB = BC/TanD(A)

AB = AG+GB

VOLUME REQUIRED FOR EXTENSION
OF GIVEN WIDTH

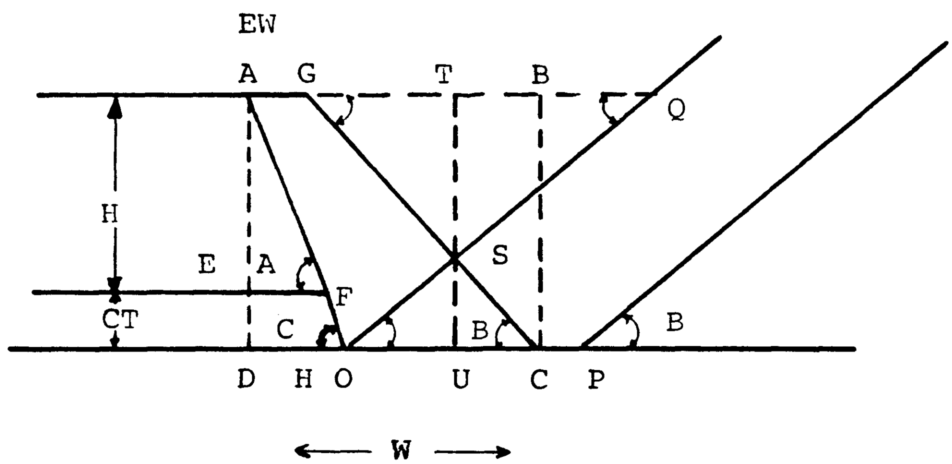

Figure 51 . Extended Volume Case 1

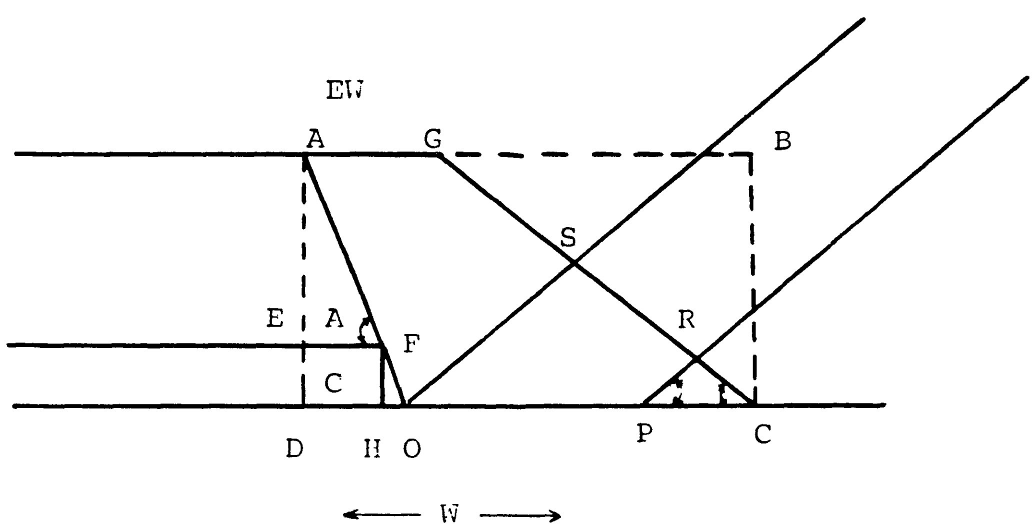

Figure 52 . Extended Volume Case 2

FH = ED

HO = FH/TanD(C)

DP = EF + HO + OP

PC = AB - DP

Area ABCD = AB * AD

Area GBC = GB * BC/2.0

Area AEF = AE * EF/2.0

Area EFOD = EF*ED + FH*HO/2.0

Extended Area = AB*AD - (GBxBC/2.0+AE·EF/2.0+(EF*ED+FH*H0/2).

$$=(EW+\frac{H+G}{TanA})\cdot(H+CT)-(H+CT^2/2 \cdot TanA + H \cdot CT+CT^2/TanC)$$

<u>EXTENDED AREA CALCULATION FOR CASE 2</u>

From Figure 52, extended area is equal to:

EA(AGPO) = Area ABCD - Area GBC - Area AEF - Area EFOD - Area PRC

Area ABCD = AB*AD

Area GBC = GB*BC/2.0

Area AEF = AEXEF/2.0

Area EFOD - EF x ED + FH * HO/2.0

Area PRC = PC**2.0/(4*TanD(B))

EA = AB*AD - GB*BC/2.0-AE*EF/2.0-EF*ED+FH*HO/2.0 -
PC**2.0/(4*TanD(B))

$$EA = (EW+\frac{H+CT}{TanA})\cdot(H+CT)-((H+CT)^2/2\cdot TanA+H\cdot CT+CT^2/TanC +$$

$$(EW+\frac{H+CT}{TanA})+H/TanA + CT(TanC+W)$$

Calculation of the Volume Not Be Rehandled

The portion of this extended volume will not be rehandled because it is already within the limits of the spoil area.

There are also two different cases for calculation of this spoil volume already in the spoil pit area.

Figure 53 , and 54 illustrates these two different cases. The volume not be rehandled will be the product of the cross-sectional area multiplied by the cut length.

Case 1

The amount of material has already been spoiled from the pit extension in the spoil pit area is the Area OSC in Figure 53 .

Area OSC = SU**2/TanD(B)

Height SU = TU - TS 1

TS = TQ*TanD(B) 2

TQ = AG/2 where 3

AQ = AY + YQ where

AY = AE/TanD(A) + ED/TanD(C)

YQ = AD/TanD(B)

AQ = AE/TanD(A) + ED/TanD(C) + AD/TanD(B) 4

Substituting Equation 4 into 3,

TQ = (AE/TanD(A) + ED/TanD(C) + AD(TanD(B))/2

Substituting TQ into 2

$$TS = (AE/TanD(A) + ED/TanD(C) + AD/TanD(R))\ \frac{*TanD(B)}{2}$$

Substitute TS into Equation 1,

VOLUME ALREADY SPOILED IN EACH
CROSS-SECTION FROM
THE PIT EXTENSION

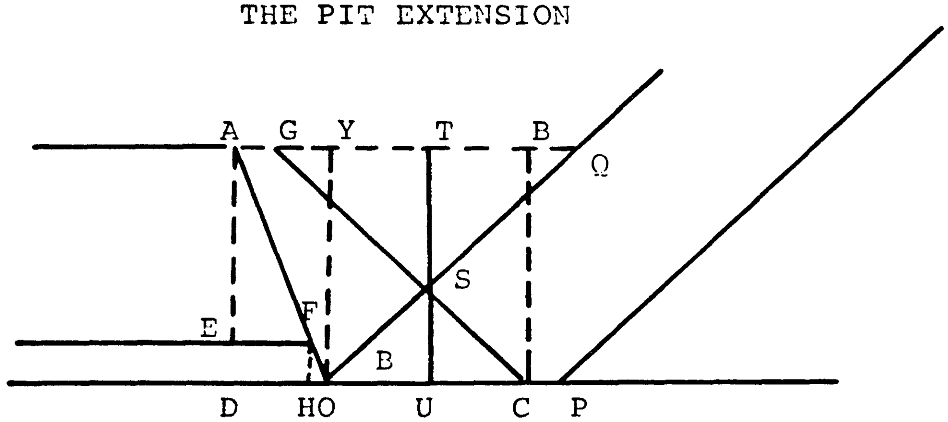

Figure 53. Volume already spoiled Case 1

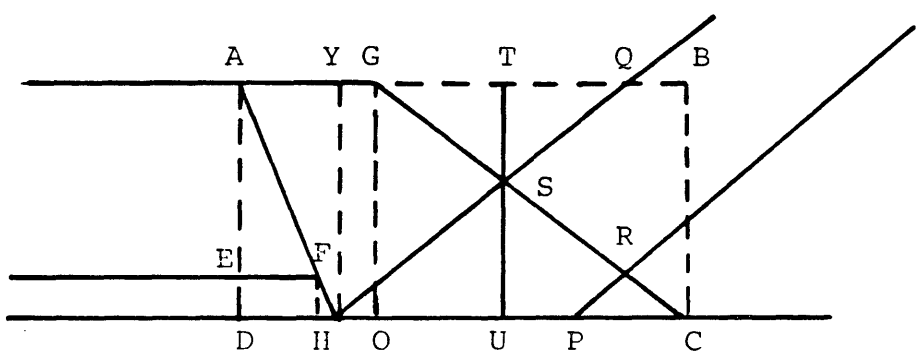

Figure 54. Volume already spoiled Case 2

Height SU = TU - (AE/TanD(A) + ED/TanD(C) + AD/TanD(B))

* TanD(B)/2.0 .

Since,

TU = (H+CT) = AD

AE = H

ED = CT

Height SU = (H+CT) - (H/TanD(A)+ CT/TanD(C) + (H+CT)/TanD(B))

* TanD(B)/20 .

Therefore, area equation becomes,

Area OSC = (H+CT)-(H/TanD(A) + CT/TanD(C) + (H_CT)/TanD(B))

* TanD(B)/2 **2 / TanD(B) .

Case 2

For this case, area already spoiled into spoil cross sections from the extended bench is area OSRP in Figure 54.

Area OSRP = Area OSG - Area PRC

Area OSC is the same as in Case 1.

Area PRG = PG/2 * TanD(B) * PG = PG **2 * TanD(B)/2.0

PC = DC-DP

DC = AG + AD/TanD(B)

DP = AE/TanD(A) + ED/TanD(C) + OP

Since AG = EQ = Extended Width

AE = H = Height

ED = CT = Coal Thickness

OP = W = Pit Width

Therefore,

DC = EW + (CT+H)/TanD(B)

DP = H/TanD(A) + CT/TanD(C) + W

PC becomes

PC = EW + (CT+H)/TanD(B) - (H/TanD(A) + CT/TanD(C) + W)

Area PRC becomes,

PRC = EW+(CT+H)/TanD(B) - (H/TanD(A) + CT/TanD(C)+W) **2

* TanD(B)/2.0

APPENDIX C

Effective Dragline Reach Determination for

Pull Back Machine

Rehandle Volume Calculation for

for Pull Back Machine

Rehandle Volume Calculation for Dozer

<u>Effective Reach Determination of the Pull Back Machine</u>

Referring to Figure 55, effective reach of the pull back machine can be determined as follows:

Assuming that the dozer will knock the spoil reach to leveled bench, the pull back machine will have to operate behind the point M in Figures 55 and should be able to reach to point J.

Then effective reach of the pull back machine will be equal to,

$$EFRPB = QH + HP + NO + OM \text{ ----------------------------- } (1)$$

Where

$$QH = CT/TanC + WX - CT\left(\frac{1}{TanB} + \frac{1}{TanC}\right) - \frac{1}{\left(1 + \frac{TanA}{TanB}\right)}$$

$$HP = W$$

$$NO = EDR - H/TanA - CT/TanC - W \quad \text{(EDR is the average effective reach of the primary machine)}$$

$$OM = WX - \frac{(WX+W)}{4}$$

Substituting these into equation 1

$$EFRPB = EDR - H/TanA + \frac{7WX+W}{4} - CT \cdot \left(\frac{1}{TanB} - \frac{1}{TanC}\right) \cdot \frac{1}{\left(1 + \frac{TanA}{TanB}\right)}$$

EFRPB: Effective reach of the pull back machine (feet)

EDR: Average effective reach of the primary machine (feet)

H: Overburden height (feet)

CT: Coal thickness (feet)

W: Pit width (feet)

A: Highwall angle (degrees)

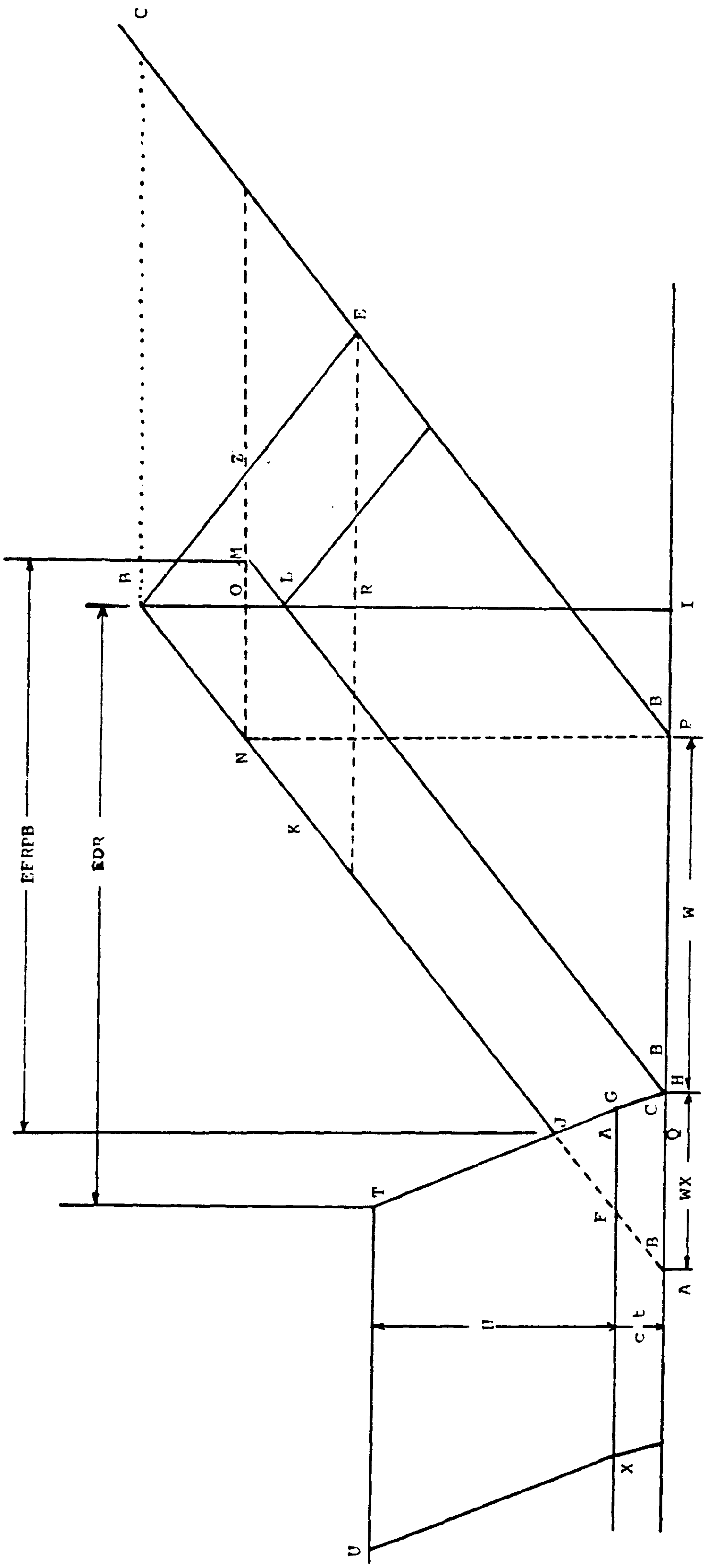

Figure 55 : Cross Sectional View of the Pit Geometry for the Pull Back Method.

B : Spoil Angle (degrees).

C : Coal Free Angle (degrees).

WX : (feet).

WX is determined in the following way.

Area of the spoil cross section BJHPE in Figure 55 should be equal to overburden area UTGX plus the swell.

Area BJHPE = Total area ABCP - Coal area AFGH - area of triangle BEC - area of the overburden FGJ

Where:

Total area ABCP = (WX+W) * (WX + EDR - H/Tan A - CT/TanC)*Tan(B)

$$\text{Coal area AFGH} = WX*CT - \frac{CT^2}{2}\left(\frac{1}{TanB} + \frac{1}{TanC}\right)$$

$$\text{Area of the overburden FGJ} = (WX-CT*(1/TanB + 1/TanC))^2 * \frac{1}{2*(1/TanA+1/TanB)}$$

$$\text{Area of the triangle BEC} = (WX+W)^2 * \frac{TanB}{4.0}$$

Substituting these into equation 2 and rearranging the terms,

$$\text{Area of the Spoil BJHPE} = \left(3/4\ \mathrm{TanB} - \frac{1}{2(1/\mathrm{TanA} - 1/\mathrm{TanB})}\right) \cdot WX^2 +$$

$$\left(\left(\mathrm{TanB} \cdot \left(EDR - \frac{H}{\mathrm{TanA}} - \frac{CT}{\mathrm{TanC}} - \frac{CT}{\mathrm{TanB}} + \frac{W}{2}\right)\right) + 2 \cdot CT \cdot \left(\frac{1}{\mathrm{TanB}} + \frac{1}{\mathrm{TanC}}\right) \right) \cdot WX$$

$$W \cdot \mathrm{TanB} \cdot \left(EDR - \frac{H}{\mathrm{TanA}} - \frac{CT}{\mathrm{TanC}}\right) + \frac{CT^2}{2} \cdot \left(\frac{1}{\mathrm{TanB}} + \frac{1}{\mathrm{TanC}}\right) - CT^2 \cdot \left(\frac{1}{\mathrm{TanB}} + \frac{1}{\mathrm{TanC}}\right)^2 \cdot$$

$$\frac{1}{2(1/\mathrm{TanA} + 1/\mathrm{TanB}} - W^2 \cdot \frac{\mathrm{TanB}}{4} \qquad \text{--}(3)$$

This area BJHPE must be equal to $W \cdot H \cdot (1+SF)$

Substitute this area for the left side of the equation and assume

$$a = \left(3/4\ \mathrm{TanB} - \frac{1}{2(1/\mathrm{TanA} + 1/\mathrm{TanB})}\right)$$

$$b = \mathrm{TanB} \cdot \left(EDR - \frac{H}{\mathrm{TanA}} - \frac{CT}{\mathrm{TanC}} - \frac{CT}{\mathrm{TanB}} + \frac{W}{2}\right) + 2 \cdot CT \cdot (1/\mathrm{TanB} + 1/\mathrm{TanC})$$

$$C = W \cdot \mathrm{TanB} \cdot (\mathrm{EDR} - \frac{H}{\mathrm{TanA}} - \frac{CT}{\mathrm{TanC}}) + \frac{CT^2}{2} \cdot (\frac{1}{\mathrm{TanB}} + \frac{1}{\mathrm{TanC}}) - CT^2 \cdot (1/\mathrm{TanB} + 1/\mathrm{TanC})^2 \cdot$$

$$\frac{1}{2 \cdot (1/\mathrm{TanA} + 1/\mathrm{TanC})} - W^2 \cdot \frac{\mathrm{TanB}}{4} - W \cdot H \cdot (1+SF)$$

Then the equation becomes,

$$a\, WX^2 + b\, WX + C = 0$$

The roots of this equation can be found from

$$WX = \frac{-b \pm (b2-4a \cdot c)^{1/2}}{2a}$$

Once the WX is determined, required dragline operating radius can be calculated.

Rehandle Volume Calculation for Pull Back Machine

Referring to Figure 55,

Rehandle area JNMH = Total area of trapezoid ANMH -

Area of the coal AF GH - Area of triangle FGJ.

Where:

Total area of trapezoid (ANMH) $= WX \cdot TanB \cdot (EDR - \frac{H}{TanA} - \frac{CT}{TanC} + \frac{3WX}{4} + \frac{W}{4})$

Area of the Coal (AFGH) $= WX.CT - \frac{CT^2}{2}(\frac{1}{TanB} + \frac{1}{TanC})$

Area of the Triangle (FGJ) $= (WX-CT.(\frac{1}{TanB} + \frac{1}{TanC}))^2 \cdot \frac{1}{2.(\frac{1}{TanA} + \frac{1}{TanB})}$

$\therefore$

Rehandle Area (JNMH) $= WX.TanB.(EDR - \frac{H}{TanA} - \frac{CT}{TanC} + \frac{3WX}{4} + \frac{W}{4}$

$WX.CT - \frac{CT^2}{2}(\frac{1}{TanB} + \frac{1}{TanC}$

$(WX-CT.(\frac{1}{TanB} + \frac{1}{TanC}))^2 \cdot \frac{1}{2.(\frac{1}{TanA} + \frac{1}{TanB})}$

Rehandle Volume = Rehandle area * X

Where X is the cut length.

Rehandle Volume for Dozer

Referring to Figure 55,

Area of the dozer rehandle is = BNZ

$$\text{Area BNZ} = \left(\frac{WX+W}{4}\right) \cdot \text{Tan B} \cdot \left(\frac{WX+W}{4}\right)$$

$$= \left(\frac{WX+W)^2}{16} \cdot \text{Tan B}\right)$$

$$\text{Dozer Rehandle Volume} = \left(\frac{WX+W)^2}{16} \cdot \text{Tan B}\right) \cdot X$$

APPENDIX D

Description of Model's Input and Program Variables

TABLE 19.—LIST OF INPUT VARIABLES FOR ALL MODELS

NAME	DEFINITION	UNITS	DESCRIPTION
A	Highwall Angle	Degrees	Angle of the overburden highwall.
AV	Availability	Decimal Fraction	Machine's mechanical availability.
BC	Bucket Capacity	Cubic Yards	Bucket capacity of the selected machine.
BPT	Bucket Positioning Time	Seconds	The time it takes to position the bucket over the leading point.
C	Coal Highwall Angle	Degrees	The angle of the coal face.
CABHT	Cab Height	Feet	The height where drag ropes enter into the dragline frame.
CABRAD	Cab Radius	Feet	The dragline tub radius.
CD	Coal Density	Pounds/ Cubic Feet	Density of inplace coal.
CDBH	Chop Down Bench Height	Feet	Height of the overburden to be removed for bench preparation.
CLT	Clearing Time	Seconds	The time it takes to prepare the dragline to walk
CT	Coal Thickness	Feet	Average thickness of the coal in the area to be mined.
CRF	Capital Recovery Factor	Decimal Fraction	
DDFDF(J)	Dragline Distance from Digging Face	Feet	The distance from the centroid of the dragline to the crest of the digging face for the position J.

NAME	DEFINITION	UNITS	DESCRIPTION
DDFH(J)	Dragline distance from Highwall	Feet	The distance from the centroid of the dragline to the crest of the highwall for the position J.
DIC	Dragline Investment Cost	Dollars	Initial investment made on the dragline. Includes freight and ballast costs.
DOL	Dragline Operating Life	Years	Dragline Depreciation Years.
DR	Dragline Radius	Feet	Dragline operating radius defined as the horizontal distance between the centroid of the tub and the boom point.
DT	Digging Time	Seconds	The time it takes to fill a bucket load.
FA	Digging Face Angle	Degrees	Maximum angle for the digging face.
FF	Fill Factor	Decimal Fraction	Bucket Fill Factor.
H	Overburden Height	Feet	Average overburden height for the property.
ITIP	Interest Taxes Insurance Percentage	Decimal Fraction	Percentage of the average annual investment to calculate the interest, taxes, insurance costs.
IFLAG	Input Flag	Integer	Control to specify the model which mining method to be used (one lift or two lifts). Must be either 0 or 1. IFLAG = 0 one lift operation IFLAG = 1 two lifts
JF	Job Factor	Decimal Fraction	Represent the fraction of time dragline is able to work.

TABLE 19. (Continued)

NAME	DEFINITION	UNITS	DESCRIPTION
LR	Labor Rates	$/Hour	Hourly wages paid to the dragline operator, oiler and groundman on average.
MT	Machine Type		Initials of machine manufacturer and the dragline models (like BE 1570).
N	Number of Cross Sections	Integer	Number of the cross sections to be considered for the spoil area.
NPK	Number of positions for key	Integer	Used to specify the position number of the dragline at last key cut position.
NTP	Number of Total Positions	Integer	Used to specify the position number of the dragline at the last main cut position. This number is same as total number of positions to mine the cut.
NFSIKP	Number for second initial key position	Integer	Used to specify the position number of the dragline for second lift initial key cut position.
NFSLKP	Number for second last key position	Integer	Used to specify the last key cut position number for the second lift.
NFSTP	Number for Second Total Positions	Integer	This is the total number of positions dragline requires to mine top and bottom lifts. This number also specifies the position number for the last dragline position.
P	Positioning	Feet	The safety distance from the centroid of the dragline to the crest of either digging face or highwall. This dimension is used in the calculation of required dumping radius.

TABLE 19.—(Continued)

NAME	DEFINITION	UNITS	DESCRIPTION
PcH	Power consumed in an hour	Kilowatt Hours	Power consumption of the machine which will be used in operating cost calculation.
PCKH	Power Cost per Kilowatt Hours	Dollars/ Kilowatt Hrs.	Power cost per kilowatt/hours.
RF	Recovery Factor	Decimal Fraction	Expected recovery percentage for the inplace coal.
SCC	Swing Curve Constants	Seconds	Y intercept of the swing angle vs. swing time curve.
SF	Swell Factor	Decimal Fraction	Factor defining the expected swell or increase in volume of the overburden.
SH	Scheduled Hours	Hours/year	Scheduled hours/year for stripping operation.
ST1	Swing Time 1	Seconds	Swing time obtained from the swing angle vs. swing time curve for 90 degree swing angle.
ST2	Swing Time 2	Seconds	Swing time for the 120^{o} swing angle.
X	Cut length	Feet	This dimension is the length of the overburden to be removed by the dragline to simulate its operation. Cut length determines the distance between set up patterns. This length is also equal to the length of the spoil pile.
XD	X - Coordinate for Chop Down Bench Segment	Feet	The distance from the centroid of the chop down bench segment to the crest of the highwall.

TABLE 19. (Continued)

NAME	DEFINITION	UNITS	DESCRIPTION
YD	Y - Coordinate for Chop Down Bench Segment	Feet	The distance from the centroid of the chop down bench segment to the crest of the digging face.
W	Pit Width	Feet	The width of the overburden cut, the width of the coal uncovered, and the width of the spoil bank.
WK	Width of the Key	Feet	Key cut width at the top of the coal surface.
WS	Walking Speed	Feet/Sec.	Walking speed of the dragline.

NAME	DEFINITION	UNITS	DESCRIPTION
AS(J)	Angle of Swing	Degrees	Swing angle made from the first dragline position to spoil chop down material to the J'th cross section - temporary storage.
AD	Area Disturbed	Square Feet	Area of the overburden, the dragline is able to remove in a year. This variable is used to calculate the coal tonnage to be uncovered by the dragline.
ASA(K)	Average Swing Angle	Degrees	Weighted average swing angle the dragline makes from a given position.
AVI	Average Annual Investment	$/Year	Average annual investment to be used for interest, taxes, and insurance cost calculations.
CDVOL	Chopped Down Volume	Cubic Feet	Volume of the chop down bench segment to be removed for bank preparation.
CDASA	Chop Down Average Swing Angle		Chop down average swing angle - temporary storage.
CONV	Convert		Factor to convert angles from radians to degrees.
CDSA(J)	Chop Down Swing Angle	Degrees	Total swing angle made from the first dragline position to spoil the chop down material into the J'th cross section. This is an intermediate variable to be used for the weighted average swing angle calculation to completely remove the chop down bench segment.

NAME	DEFINITION	UNITS	DESCRIPTION
CTON	Coal Tonnage	Ton	Tons of recoverable coal, uncovered by the dragline in a year.
CTHR	Coal Tonnage per Hour	Ton	Tons of recoverable coal uncovered by the dragline in an hour.
CV	Coal Volume	Cubic Feet	Volume of the coal the dragline can uncover in a year.
DAP	Dragline Annual Production	Cubic Yards	Expected annual dragline production.
DCH	Dragline Cost Per Hr.	Dollars/Hour	Dragline hourly investment cost based on the straight line depreciation.
DCY	Dragline Cost Per Yr.	Dollars/Year	Dragline annual investment cost based on straight line depreciation.
DFXS	Distance from the Cross Section	Feet	Horizontal distance required from the dragline centroid to the first cross section where dragline would spoil the material to sufficient height without causing any rehandle. This variable is used to check dragline initial dumping point to determine if the overburden is shallow or medium height.
DOR	Dragline Operating Radius	Feet	Required dragline operating radius by the physical dimensions of the pit.
DPPH	Dragline Production per Hour		Dragline production per hour based on the calculated weighted average cycle time.

TABLE 20.—(Continued)

NAME	DEFINITION	UNITS	DESCRIPTION
DTXS (I,O)	Distance to cross section	Feet	The horizontal distance from the dragline centroid at the I'th position to the last spoil cross section for the previous cut segment. This variable is used to determine possible initial spoil point for each dragline location.
ET	Excavating Time	Hours	Number of hours the machine is actually expected to excavate, taking into account mechanical availability and the job factor.
FACT	Final Average Cycle Time	Seconds	Overall weighted average cycle time for the whole cut.
FASA	Final Average Swing Angle	Degrees	Overall weighted average swing angle for the whole cut.
ITI	Interest, taxes, insurance	Decimal Fraction	Interest, taxes and insurance percentage.
ITIH	Interest, taxes, insurance per hour	Dollar	Interest, taxes and insurance cost per hour.
J1			Number of total positions for the first lift - temporary storage.
JM			Number for the initial dragline position before starting to make the key cut for the either lift.
LCH	Labor Cost Per Hour	Dollar	Total labor cost per hour assuming three crew members.

TABLE 20. (Continued)

NAME	DEFINITION	UNITS	DESCRIPTION
M			The number for the immediate dragline digging position - temporary storage.
MI			Number for the last key cut position of the top lift - temporary storage.
MCH	Maintenance Cost Per Hour	Dollar	Machine maintenance cost per hour. Calculated on the assumption of 6 cents per cubic yard of material removed.
NOCPH	Number of Cycles Per Hr.		Number of cycles the dragline can make in an hour.
PCOSTH	Power Cost	Dollar	Dragline power cost per hour.
PRCCD	Percent Chop Down	Decimal Fraction	Percentage of chop down material with respect to total overburden removal.
RK		Decimal Fraction	Factor to adjust the cycle times for the key cut, chop down cut, and the main cut positions. RK = 1 for the main cut RK = 1.5 for the key cut and chop down
SA	Swing Angle	Degrees	Swing angle made to spoil the cut material into a cross section from a position - temporary storage.
TVRH	Total Volume Rehandled	Cubic Feet	Total volume rehandled per year.
TOPKEY	Top of the Key Cut	Feet	Width of the key cut at the top of the overburden.

NAME	DEFINITION	UNITS	DESCRIPTION
TCT(K)	Total Cycle Time	Seconds	Total excavating time at Kth position.
TCH	Total Cost Per Hour	Dollar	Total ownership and operating cost per hour.
TCTON	Total Cost Per Ton	Dollars/Ton	Dragline ownership and operating cost per ton of recoverable coal.
TCYD	Total Cost Per Yard	Dollars/Cubic Yard	Dragline ownership and operating cost per cubic yard.
TNOC	Total Number of Cycles		Total number of cycles required to remove the whole cut.
T2		Feet	Minimum horizontal distance required from the crest of the highwall to the spoil crest in order to spoil the material without rehandle.
TOCTON	Total Operating Cost Per Ton	Dollar/Ton	Dragline operating cost per ton of recoverable coal.
TOCYD	Total Operating Cost Per Yard	Dollar/Ton	Dragline operating cost per cubic yard.
TOTCT	Total Cycle Time	Seconds	Cumulative sum of the excavating time for all positions.
TOCH	Total Operating Cost Per Hour	Dollar	Total dragline operating cost per hour.
TOWCH	Total Ownership Cost per Hour	Dollar	Total dragline ownership cost per hour.

NAME	DEFINITION	UNITS	DESCRIPTION
TOWCTN	Total Ownership Cost Per Ton	Dollar	Dragline ownership cost per ton of recoverable coal.
TOTWT	Total Walking Time	Seconds	Cumulative sum of the walking time for all positions.
TT(K)	Total Time	Seconds	Total excavating and walking times at K'th position.
TTSS	Total Time Spent for the Segment	Seconds	Total time the dragline spends for the removal of cut segment.
TVS(K)	Total Volume Spoiled	Cubic Feet	Total volume spoiled from the K'th position.
TVSFK	Total Volume Spoiled for Key	Cubic Feet	Total volume spoiled from the key cut - temporary storage.
TVSFP	Total Volume Spoiled for the Prime Cut	Cubic Feet	Total volume spoiled from the main cut - temporary storage.
TVSLKP	Total Volume Spoiled Last Key Position	Cubic Feet	Volume spoiled from the last key cut position of the dragline - temporary storage.
TWSA	Total Weighted Swing Angles	Degrees - cubic feet	Sum of the weighted swing angles for the cut segment.
UIL	Unit Interval Length	Feet	Unit length of the slice over which each cross section has influence.
UV(K,J)	Unit Volume	Cubic Feet	Spoil volume capacity of the J'th cross section for the Kth position.

NAME	DEFINITION	UNITS	DESCRIPTION
UVT(J)	Unit Volume Total	Cubic Feet	Permanent storage for the amount of material already spoiled into each cross section.
VOL(K)	Volume for the K'th Position	Cubic Feet	Volume of the material can be removed from the K'th dragline position.
VSFFKP	Volume Spoiled from the First Key Position	Cubic Feet	Volume of the material spoiled from the last key cut position for the lower lift-temporary storage.
XD1	X Distance 1	Feet	X - Coordinate for the centroid of the chop down bench segment with respect to first dragline position.
YD1	Y Distance 1	Feet	Y - Coordinate for the centroid of the chop down bench segment with respect to first dragline position.
WSA(K)	Weighted Swing Angle	Degrees-cubic feet	Cumulative sum of the weighted swing angles for the K'th position.
WD(K)	Walking Distance	Feet	Walking distance of the dragline from the (K-1)'th position to the K'th position.
WT(K)	Walking Time	Second	Time it takes to walk the dragline from (K-1)th position to the K'th position.

NAME	DEFINITION	UNITS	DESCRIPTION
ACT	Average Cycle Time	Seconds	Average cycle time for chop down bench segment.
AST	Average Swing Time	Seconds	Average swing time for chop down bench segment.
CDASA	Chop Down Average Swing Angle	Degrees	Average swing angle for chop down bench segment.
DEPTH	Depth of the Overburden	Feet	Height of the overburden - temporary storage.
EV	Extended Volume	Cubic Feet	Volume required to extend the bench.
EVB	Extended Volume B	Cubic Feet	Volume required to extend the bench - temporary storage.
EW	Extended Width	Feet	Required pit width extension.
HE	Horizontal Extension	Feet	Effective reach gained by chopping down.
HG	Height Gained	Feet	Effective overburden height reduction by chopping down.
NOC	Number of Cycles		Number of cycles made to remove chop down bench segment.
PDR	Dragline Reach	Feet	Dragline operating radius - temporary storage.
SRG	Spoil Room Gained	Cubic Feet	Spoil room gained by chopping down.
SWELL	Swell Factor	Decimal Fraction	Temporary storage for swell factor.

TABLE 21. (Continued)

NAME	DEFINITION	UNITS	DESCRIPTION
TCTCD	Total Cycle Time - Chop Down	Seconds	Total time spent for chopping down the segment.
TVSB(K)	Total Volume Spoiled for Bench	Cubic Feet	Total volume spoiled for bench extension from the Kth position.
VOLASC	Volume Already Spoiled for the Cut	Cubic Feet	Volume already spoiled into the pit by bench extension for the whole cut segment.
VOLAS	Volume Already Spoiled	Cubic Feet	Volume already spoiled into the pit by bench extension for a cross section.
XD	X - Distance	Feet	The X coordinate of the centroid for the chop down bench segment with respect to crest of the highwall.
YD	Y - Distance	Feet	The Y coordinate of the centroid for the chop down bench segment.

SELECTION AND TWO MACHINE PULL BACK MODEL

NAME	DEFINITION	UNITS	DESCRIPTION
ACT	Average Cycle Time	Seconds	Pull back machine average cycle time.
CA	Constant A		Constant A of the second degree equation - temporary storage.
CB	Constant B		Constant B of the second degree equation - temporary storage.
CC	Constant C		Constant C of the second degree equation - temporary storage.
CONST 3	Constant		Temporary storage used to break up pull back rehandle equation.
CONST 4	Constant		Temporary storage used to break up pull back rehandle equation.
CV	Coal Volume	Cubic Feet	Volume of the recoverable coal can be uncovered in a year.
DOCPH	Dozer Operating Cost Per Hour	Dollar/Hour	Operating cost of the dozer in an hour.
DOPPH	Dozer Production Per Hour	Cubic Feet/ Hour	Required dozer production per hour to level the spoil ridge.
DOWCPH	Dozer Ownership Cost Per Hour	Dollar/Hour	Dozer ownership cost in an hour.
DPERRH	Dozer Percent Rehandle	Decimal Fraction	Percentage of the ridge material leveled by the dozer with respect to bank overburden removed.

NAME	DEFINITION	UNITS	DESCRIPTION
DPPH(1)	Primary Dragline Production Per Hour	Cubic Yard/ Hour	Primary dragline production in an hour.
DPPH(2)	Pull Back Dragline Production Per Hour	Cubic Yard/ Hour	Pull back dragline production in an hour.
DRV	Dozer Volume	Cubic Feet	Amount of material rehandled by the dozer for a given cut.
ESR	Effective Spoil Reach	Feet	Effective dragline reach for primary machine. This reach is the average for the effective reach at initial spoil point and the effective reach of the final spoiling point.
NOCPH	Number of Cycles Per Hour		Number of cycles pull back machine can make in an hour.
PBACT	Pull Back Average Cycle Time	Seconds	Pull back machine average cycle time for 180 degree swing angle.
PBASA	Pull Back Average Swing Angle	Degrees	Pull back machine average swing angle assumed to be 180^{o}.
PBAP	Pull Back Annual Production	Cubic Yard/ Year	Pull back machine annual production capacity.
PBAST	Pull Back Average Swing Time	Seconds	Swing time for 180^{o} swing angle.
PBAV	Pull Back Availability	Decimal Fraction	Mechanical availability of the pull back machine.
PBBC	Pull Back Bucket Capacity	Cubic Yard	Bucket capacity of the pull back machine.

TABLE 22. (Continued)

NAME	DEFINITION	UNITS	DESCRIPTION
PBBPT	Pull Back Bucket Positioning Time	Seconds	Pull back machine bucket positioning time to calculate cycle time.
PBCLT	Pull Back Clearing Time	Seconds	Pull back machine preparation time to walk.
PBDR	Pull Back Dragline Bench		Pull back dragline operating radius, (from centroid to the boom point).
PBDT	Pull Back Digging Time	Seconds	Digging time per bucket load for pull back machine. This is used to calculate cycle time for the machine.
PBFF	Pull Back Fill Factor	Decimal Fraction	Bucket fill factor for the pull back machine.
PBJF	Pull Back Job Factor	Decimal Fraction	Job factor for the pull back machine.
PBMPPH	Pull Back Machine Production per Hour	Cubic Yard/ Hour	Pull back machine output in an hour - temporary storage.
PBSCC	Pull Back Swing Curve Constant	Seconds	Y - intercept of the pull back machine swing angle vs. swing time curve.
PBSH	Pull Back Scheduled Hours	Hours	Number of hours pull back machine is scheduled to work.
PBSM	Pull Back Slope M		Slope of the pull back swing angle vs. swing time curve.
PBST1	Pull Back Swing Time 1	Seconds	Pull back machine swing time for 90^{o} swing angle.

NAME	DEFINITION	UNITS	DESCRIPTION
PBST2	Pull Back Swing Time 2	Seconds	Pull back swing time for 120^{o} swing angle.
PBWS	Pull Back Walking Speed	Feet/Seconds	Walking speed of the pull back machine.
PERREH	Percent Rehandle	Decimal Fraction	Percentage of material to be rehandled by the pull back machine.

APPENDIX E

Property Characteristics and the
Tabulated Dragline Data for the Case Study

PROPERTY CHARACTERISTICS:

Average Coal Thickness	5.57	feet
Highwall Angle	63.4	degrees
Spoil Angle of Repose	35.0	degrees
Coal Highwall Angle	76.0	degrees
Swell Factor	122.0	per-cent
Coal Recovery	88.0	per-cent
Cut Length	100.0	feet
Drainage Ditch Width	10.0	feet

JOB CHARACTERISTICS:

Schedules Hours Per Year	6800.0	hours/year
Mechanical Availability	88.0	per-cent
Job Factor	85.0	per-cent

JOB ECONOMIC CHARACTERISTICS:

Depreciation Life	20.0	years
Interest, Insurance & Taxes	16.0	per-cent
Average Labor Cost	13.0	dollars/hour
Power Cost	3.0	cents per KWH/H

MARION 8200-12A

AVERAGE SWING ANGLE (DEGREES):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	46.80	48.46	51.01	53.67	78.50	96.26
50	56.66	58.85	61.93	62.64	64.81	99.37
70	67.93	70.44	73.81	75.77	77.01	105.95*
90*	97.55	99.44	100.41	96.73	77.52**	78.89**
110**	104.10	100.75	98.22	96.12	94.40	93.10
130**	131.88	128.54	125.22	123.64	120.97	117.85

* Side casting with 20 ft. chop down
** Extended bench with 20 ft. chop down

AVERAGE CYCLE TIME (SECONDS):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	64.81	63.29	62.41	62.33	66.39	69.40
50	66.75	65.18	64.32	63.58	63.31	70.17
70	71.15	69.38	68.19	67.51	67.18	64.76*
90*	78.84	77.75	77.04	75.62	75.78**	75.90**
110**	77.74	76.91	76.23	75.76	75.02	74.14
130**	81.43	80.29	79.70	78.31	77.64	77.17

MARION 8200-12A

PRODUCTION RATE (BCY/HR):

	PIT WIDTH					
OB.HT.	100	120	140	160	180	200
30	3084	3139	3195	3196	3027	2859
50	2971	3083	3084	3139	3139	2859
70	2803	2859	2915	2971	2971	3084*
90*	2523	2579	2579	2635	2635**	2635**
110**	2579	2579	2635	2635	2635	2691
130**	2467	2466	2522	2523	2579	2579

* Side casting with 20 ft. chop down
** Extended bench with 20 ft. chop down

TONS OF COAL MINED PER YEAR (10^3 T/YR):

	PIT WIDTH					
OB.HT.	100	120	140	160	180	200
30	2456	2501	2546	2546	2412	2278
50	1420	1474	1474	1501	1501	1367
70	957	976	995	1014	1014	1052*
90*	670	685	685	700	625**	625**
110**	365	389	415	429	439	457
130**	197	234	266	287	309	323

MARION 8200-12A

OWNERSHIP COST PER TON RECOVERED ($/TON):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	0.88	0.86	0.84	0.84	0.84	0.94
50	1.51	1.46	1.46	1.43	1.43	1.57
70	2.25	2.20	2.16	2.12	2.12	2.04*
90*	3.21	3.14	3.14	3.07	3.44**	3.44**
110**	5.88	5.52	5.18	5.02	4.90	4.70
130**	10.93	9.20	8.08	7.50	6.95	6.66

* Side casting with 20 ft. chop down
** Extended bench with 20 ft. chop down

OPERATING COST PER TON RECOVERED ($/TON):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	0.73	0.73	0.73	0.73	0.73	0.74
50	1.23	1.22	1.22	1.22	1.22	1.24
70	1.74	1.73	1.72	1.72	1.72	1.71*
90*	2.27	2.26	2.26	2.25	3.28**	3.27**
110**	5.52	5.18	4.93	4.77	4.66	4.54
130**	9.97	8.40	7.48	6.95	6.52	6.25

MARION 8200-12A

TOTAL COST PER TON OF COAL RECOVERED ($/TON):

OB.HT.	PIT WIDTH 100	120	140	160	180	200
30	1.61	1.59	1.57	1.57	1.63	1.69
50	2.74	2.68	2.68	2.65	2.65	2.85
70	3.98	3.93	3.88	3.84	3.84	3.75*
90*	5.48	5.40	5.40	5.33	6.72**	6.71**
110**	11.40	10.71	10.11	9.79	9.56	9.24
130**	20.90	17.60	15.56	14.45	13.47	12.92

* Side casting with 20 ft. chop down
** Extended bench with 20 ft. chop down

TOTAL COST PER CUBIC YARD OF OVERBURDEN REMOVED ($/LCY):

OB.HT.	PIT WIDTH 100	120	140	160	180	200
30	0.15	0.15	0.15	0.15	0.16	0.16
50	0.16	0.15	0.15	0.15	0.15	0.16
70	0.16	0.16	0.16	0.16	0.16	0.15*
90*	0.18	0.17	0.17	0.17	0.19**	0.19**
110**	0.19	0.19	0.19	0.19	0.19	0.19
130**	0.20	0.20	0.20	0.20	0.19	0.19

TABLE 23 : MARION 8200-12A
DRAGLINE WEIGHTED COST COMPARISON
FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT LIGNITE IN INCREMENT	100 FT. PIT WIDTH				120 FT. PIT WIDTH				140 FT. PIT WIDTH			
		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)	
		OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.
20 - 40	16.3	0.88	0.73	0.14	0.12	0.86	0.73	0.14	0.12	0.84	0.73	0.14	0.12
40 - 60	17.3	1.51	1.23	0.26	0.21	1.46	1.22	0.25	0.21	1.46	1.22	0.25	0.21
60 - 80	25.0	2.25	1.74	0.56	0.43	2.20	1.73	0.55	0.43	2.16	1.72	0.54	0.43
80 - 100	18.5	3.21	2.27	0.54	0.42	3.14	2.26	0.58	0.42	3.14	2.76	0.58	0.42
100 - 120	16.2	5.88	5.52	0.95	0.84	5.52	5.18	0.89	0.84	5.18	4.93	0.84	0.80
120 - 140	6.7	10.93	9.97	0.73	0.67	9.20	8.40	0.62	0.56	8.08	7.48	0.54	0.50
Average Ownership & Operating Cost ($/Ton)				3.23	2.74			3.03	2.58			2.89	2.48

TABLE 23 : MARION 8200-12A
DRAGLINE WEIGHTED COST COMPARISON
FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT LIGNITE IN INCREMENT	160 FT. PIT WIDTH				180 FT. PIT WIDTH				200 FT. PIT WIDTH			
		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)	
		OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.
20 - 40	16.3	0.84	0.73	0.14	0.12	0.89	0.73	0.14	0.12	0.94	0.74	0.15	0.12
40 - 60	17.3	1.43	1.22	0.25	0.21	1.43	1.22	0.25	0.21	1.52	1.24	0.26	0.21
60 - 80	25.0	2.12	1.72	0.53	0.43	2.12	1.72	0.53	0.43	2.04	1.71	0.51	0.43
80 - 100	18.5	3.07	2.25	0.68	0.42	3.44	3.28	0.64	0.61	3.44	3.27	0.64	0.60
100 - 120	16.2	5.02	4.77	0.81	0.77	4.90	4.66	0.79	0.75	4.70	4.54	0.76	0.73
120 - 140	6.7	7.50	6.95	0.50	0.47	6.95	6.92	0.46	0.44	6.66	6.25	0.45	0.42
Average Ownership & Operating Cost ($/Ton)				2.91	2.42			2.81	2.56			3.23	2.74

TABLE 23 : MARION 8200-12A
DRAGLINE WEIGHTED ANNUAL LIGNITE PRODUCTION
COMPARISON FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT RESERVE IN INCREMENT	160 FT. PIT WIDTH		180 FT. PIT WIDTH		200 FT. PIT WIDTH	
		PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)	PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)	PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)
20 - 40	16.3	2546	415	2412	393	2278	371
40 - 60	17.3	1501	259	1501	260	1367	236
60 - 80	25.0	1014	253	1014	253	1052	263
80 - 100	18.5	700	129	625	116	625	116
100 - 120	16.2	429	69	439	71	457	74
120 - 140	6.7	287	19	309	21	323	22
Average Production (Tons/Year)			1144		1114		1082

TABLE 23: MARION 8200-12A
DRAGLINE WEIGHTED ANNUAL LIGNITE PRODUCTION
COMPARISON FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT RESERVE IN INCREMENT	100 FT. PIT WIDTH		120 FT. PIT WIDTH		140 FT. PIT WIDTH	
		PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)	PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)	PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)
20 - 40	16.3	2456	400	2501	407	2546	415
40 - 60	17.3	1420	246	1474	255	1474	255
60 - 80	25.0	957	237	976	244	995	249
80 - 100	18.5	670	124	685	127	685	127
100 - 120	16.2	365	59	389	63	415	67
120 - 140	6.7	197	13	234	16	266	18
Average Production (Tons/Year)			1081		1112		1131

TABLE 23: MARION 8200-12A
DRAGLINE WEIGHTED HOURLY OVERBURDEN
PRODUCTION COMPARISON FOR VARIOUS PIT WIDTHS

		160 FT. PIT WIDTH		180 FT. PIT WIDTH		200 FT. PIT WIDTH	
OVERBURDEN INCREMENT	PERCENT RESERVES IN INCREMENT	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)
20 - 40	16.3	3196	521	3027	493	2850	466
40 - 60	17.3	3119	540	3139	543	2850	495
60 - 80	25.0	2971	743	2971	742	3084	771
80 - 100	18.5	2635	487	2635	487	2635	487
100 - 120	16.2	2635	427	2635	427	2691	436
120 - 140	6.7	2523	169	2579	173	2579	173
Average Hourly Production (BCY/HOUR)			2887		2865		2828

TABLE 23 : MARION 8200-12A
DRAGLINE WEIGHTED HOURLY OVERBURDEN
PRODUCTION COMPARISON FOR VARIOUS PIT WIDTHS

		100 FT. PIT WIDTH		120 FT. PIT WIDTH		140 FT. PIT WIDTH	
OVERBURDEN INCREMENT	PERCENT RESERVES IN INCREMENT	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)
20 - 40	16.3	3084	502	3139	512	3195	521
40 - 60	17.3	2971	514	3083	533	3084	533
60 - 80	25.0	2803	701	2859	715	2915	729
80 - 100	18.5	2525	467	2579	477	2579	477
100 - 120	16.2	2579	418	2579	418	2635	427
120 - 140	6.7	2467	165	2466	165	2522	170
Average Hourly Production (BCY/HOUR)			2967		2820		2857

MARION 8750-28A

AVERAGE SWING ANGLE (DEGREES):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	42.91	44.42	46.23	47.12	49.54	70.91
50	50.69	51.96	54.08	55.00	56.35	58.41
70	59.29	60.92	63.19	64.57	66.24	68.22
90	72.75	74.63	76.25	78.34	80.38	82.83
110*	91.39	93.08	95.09	81.90**	80.89**	81.15**
130**	116.94	113.99	112.05	110.51	106.41	104.63

* Side casting with 20 ft. chop down
** Extended bench with 20 ft. chop down

AVERAGE CYCLE TIME (SECONDS):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	64.85	63.12	62.19	61.34	61.21	65.07
50	65.83	64.05	62.94	62.19	61.62	61.58
70	68.85	66.91	65.76	64.89	64.24	63.93
90	69.07	67.82	66.96	66.49	66.15	66.19
110*	77.02	75.94	75.19	73.63**	73.20**	73.07**
130**	78.98	78.14	78.05	77.83	76.07	75.62

MARION 8750-28A

PRODUCTION RATE (BCY/HR):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	3426	3551	3551	3613	3613	3426
50	3364	3488	3551	3551	3613	3613
70	3239	3302	3364	3426	3488	3488
90	3239	3301	3302	3364	3364	3364
110*	2865	2928	2928	2990**	3052**	3052**
130**	2803	2866	2866	2866	2928	2928

* Side casting with 20 ft. chop down
** Extended bench with 20 ft. chop down

TONS OF COAL MINED PER YEAR (10^3 T/YR):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	2729	2828	2828	2878	2878	2729
50	1608	1667	1697	1697	1727	1727
70	1106	1127	1148	1170	1191	1191
90	860	877	877	893	893	893
110*	623	636	636	559**	572**	574**
130**	306	339	359	373	393	403

MARION 8750-28A

OWNERSHIP COST PER TON RECOVERED ($/TON):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	1.33	1.28	1.28	1.26	1.26	1.33
50	2.25	2.17	2.14	2.14	2.10	2.10
70	3.28	3.22	3.16	3.10	3.04	3.04
90	4.22	4.14	4.14	4.06	4.06	4.06
110*	5.82	5.70	5.70	6.49**	6.34**	6.32**
130**	11.85	10.68	10.10	9.71	9.21	9.10

* Side casting with 20 ft. chop down
** Extended bench with 20 ft. chop down

OPERATING COST PER TON RECOVERED ($/TON):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	0.72	0.72	0.72	0.72	0.72	0.72
50	1.21	1.20	1.20	1.20	1.20	1.20
70	1.70	1.69	1.69	1.68	1.68	1.68
90	2.18	2.18	2.18	2.17	2.17	2.17
110*	2.72	2.71	2.71	4.16**	4.12**	4.10**
130**	7.30	6.67	6.31	6.06	5.83	5.69

MARION 8750-28A

TOTAL COST PER TON OF COAL RECOVERED ($/TON):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	2.05	2.00	2.00	1.98	1.98	2.05
50	3.46	3.37	3.33	3.33	3.29	3.29
70	4.98	4.91	4.85	4.78	4.72	6.72
90	6.40	6.31	6.31	6.23	6.23	6.23
110*	8.54	8.41	8.41	10.65**	10.45**	10.42**
130**	19.15	17.34	16.41	15.76	15.04	14.69

* Side casting with 20 ft. chop down
** Extended bench with 20 ft. chop down

TOTAL COST PER CUBIC YARD OF OVERBURDEN REMOVED ($/LCY):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	0.20	0.19	0.19	0.19	0.19	0.20
50	0.20	0.19	0.19	0.19	0.19	0.19
70	0.20	0.20	0.20	0.20	0.19	0.19
90	0.20	0.20	0.20	0.20	0.20	0.20
110*	0.22	0.22	0.22	0.24**	0.24**	0.24**
130**	0.25	0.25	0.25	0.25	0.24	0.24

TABLE 24 : MARION 8750-28A
DRAGLINE WEIGHTED COST COMPARISON
FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT LIGNITE IN INCREMENT	160 FT. PIT WIDTH				180 FT. PIT WIDTH				200 FT. PIT WIDTH			
		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)	
		OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.
20 - 40	16.3	1.26	0.72	0.21	0.12	1.26	0.72	0.21	0.12	1.33	0.72	0.22	0.12
40 - 60	17.3	2.14	1.20	0.37	0.21	2.10	1.20	0.36	0.21	2.10	1.20	0.36	0.21
60 - 80	25.0	3.10	1.68	0.78	0.42	3.04	1.68	0.76	0.42	3.04	1.68	0.76	0.42
80 - 100	18.5	4.06	2.17	0.75	0.40	4.06	2.17	0.75	0.40	4.06	2.17	0.75	0.40
100 - 120	16.2	6.49	4.16	1.05	0.67	6.34	4.12	1.03	0.67	6.32	4.10	1.02	0.67
120 - 140	6.7	9.71	6.06	0.65	0.41	9.21	5.83	0.62	0.39	9.00	5.69	0.60	0.38
Average Ownership & Operating Cost ($/Ton)				3.81	2.23			3.73	2.21			3.71	2.20

TABLE 24 : MARION 8750-28A
DRAGLINE WEIGHTED COST COMPARISON
FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT LIGNITE IN INCREMENT	100 FT. PIT WIDTH				120 FT. PIT WIDTH				140 FT. PIT WIDTH			
		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)	
		OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.
20 - 40	16.3	1.33	0.72	0.22	0.12	1.28	0.72	0.21	0.12	1.28	0.72	0.21	0.12
40 - 60	17.3	2.25	1.21	0.39	0.21	2.17	1.20	0.38	0.21	2.14	1.20	0.37	0.21
60 - 80	25.0	3.28	1.70	0.82	0.43	3.22	1.69	0.81	0.42	3.16	1.69	0.79	0.42
80 - 100	18.5	4.22	2.18	0.78	0.40	4.14	2.18	0.77	0.40	4.14	2.18	0.77	0.40
100 - 120	16.2	5.82	2.72	0.94	0.44	5.70	2.71	0.92	0.44	5.70	2.71	0.92	0.44
120 - 140	6.7	11.85	7.30	0.79	0.49	10.68	6.67	0.72	0.45	10.10	6.31	0.68	0.42
Average Ownership & Operating Cost ($/Ton)				3.94	2.09			3.81	2.04			3.74	2.01

TABLE 24 : MARION 8750-28A
DRAGLINE WEIGHTED ANNUAL LIGNITE PRODUCTION
COMPARISON FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT RESERVE IN INCREMENT	160 FT. PIT WIDTH		180 FT. PIT WIDTH		200 FT. PIT WIDTH	
		PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)	PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)	PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)
20 - 40	16.3	2878	469	2878	465	2729	445
40 - 60	17.3	1697	294	1727	299	1727	299
60 - 80	25.0	1170	293	1131	298	1191	298
80 - 100	18.5	893	165	893	165	893	165
100 - 120	16.2	559	91	572	93	574	93
120 - 140	6.7	373	25	393	26	403	27
Average Production (Tons/Year)			1337		1350		1327

TABLE 24 : MARION 8750-28A
DRAGLINE WEIGHTED ANNUAL LIGNITE PRODUCTION
COMPARISON FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT RESERVE IN INCREMENT	100 FT. PIT WIDTH		120 FT. PIT WIDTH		140 FT. PIT WIDTH	
		PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)	PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)	PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)
20 - 40	16.3	2729	445	2828	461	2828	461
40 - 60	17.3	1608	278	1667	288	1697	234
60 - 80	25.0	1106	277	1127	282	1148	287
80 - 100	18.5	860	159	877	162	877	162
100 - 120	16.2	623	101	636	103	636	103
120 - 140	6.7	306	21	339	23	359	24
Average Production (Tons/Year)			1281		1319		1331

TABLE 24: MARION 8750-28A
DRAGLINE WEIGHTED HOURLY OVERBURDEN
PRODUCTION COMPARISON FOR VARIOUS PIT WIDTHS

		160 FT. PIT WIDTH		180 FT. PIT WIDTH		200 FT. PIT WIDTH	
OVERBURDEN INCREMENT	PERCENT RESERVES IN INCREMENT	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)
20 - 40	16.3	3613	589	3613	589	3426	558
40 - 60	17.3	3551	614	3613	625	3613	625
60 - 80	25.0	3426	857	3488	872	3488	872
80 - 100	18.5	3364	622	3364	622	3364	622
100 - 120	16.2	2990	484	3052	494	3052	494
120 - 140	6.7	2866	192	2928	196	2928	196
Average Hourly Production (BCY/HOUR)			3358		3398		3367

TABLE 24 : MARION 8750-28A
DRAGLINE WEIGHTED HOURLY OVERBURDEN
PRODUCTION COMPARISON FOR VARIOUS PIT WIDTHS

		100 FT. PIT WIDTH		120 FT. PIT WIDTH		140 FT. PIT WIDTH	
OVERBURDEN INCREMENT	PERCENT RESERVES IN INCREMENT	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)
20 - 40	16.3	3426	558	3551	579	3551	579
40 - 60	17.3	3364	582	3488	603	3551	614
60 - 80	25.0	3239	810	3302	826	3364	841
80 - 100	18.5	3239	599	3301	611	3302	611
100 - 120	16.2	2865	464	2928	474	2528	474
120 - 140	6.7	2803	188	2866	192	2866	192
Average Hourly Production (BCY/HOUR)			3201		3285		3311

MARION 8200-21R

AVERAGE SWING ANGLE (DEGREES):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	44.48	46.06	48.34	50.50	73.97	93.30
50	63.37	55.41	58.01	58.88	60.62	63.73
70	63.33	65.43	68.38	70.03	72.04	73.03
90*	93.65	94.97	95.68	96.92	58.39	109.32**
110**	95.93	93.36	91.74	90.64	89.49	88.19
130**	127.15	123.67	120.66	117.53	115.58	113.29

* Side casting with 20 ft. chop down
** Extended bench with 20 ft. chop down

AVERAGE CYCLE TIME (SECONDS):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	63.84	62.36	61.46	61.28	66.92	70.14
50	65.68	64.00	63.11	62.53	62.08	62.30
70	69.85	68.02	66.79	65.97	65.48	65.37
90*	77.80	76.79	75.97	75.47	75.34	76.61**
110**	76.81	75.87	75.31	74.87	74.48	74.00
130**	80.36	79.55	78.83	78.13	77.17	76.23

MARION 8200-21R

PRODUCTION RATE (BCY/HR):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	2922	2973	3026	3026		2660
50	2817	2922	2974	2974	2974	2974
70	2661	2713	2765	2817	2817	2869
90*	2400	2400	2452	2452	2452	2400**
110**	2399	2452	2452	2504	2504	2504
130**	2296	2347	2347	2400	2400	2452

* Side casting with 20 ft. chop down
** Extended bench with 20 ft. chop down

TONS OF COAL MINED PER YEAR (10^3 T/YR):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	2327	2369	2410	2410		2119
50	1346	1396	1421	1421	1421	1421
70	908	926	944	962	962	980
90*	637	637	651	651	651	637**
110**	380	403	413	430	437	443
130**	209	244	265	288	301	318

MARION 8200-21R

OWNERSHIP COST PER TON RECOVERED ($/TON):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	0.92	0.91	0.89	0.89	0.94	1.01
50	1.60	1.54	1.51	1.51	1.51	1.51
70	2.37	2.32	2.28	2.24	2.24	2.19
90*	3.37	3.37	3.30	3.30	3.30	3.37**
110**	5.66	5.34	5.20	4.99	4.92	4.86
130**	10.28	8.82	8.10	7.46	7.14	6.75

* Side casting with 20 ft. chop down
** Extended bench with 20 ft. chop down

OPERATING COST PER TON RECOVERED ($/TON):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	0.74	0.74	0.73	0.73	0.74	0.75
50	1.24	1.23	1.23	1.23	1.23	1.23
70	1.75	1.74	1.74	1.73	1.73	1.73
90*	2.25	2.25	2.28	2.28	2.28	2.29**
110**	4.97	4.75	4.63	4.51	4.44	4.38
130**	8.78	7.64	7.02	6.56	6.27	6.01

MARION 8200-21R

TOTAL COST PER TON OF COAL RECOVERED ($/TON):

	PIT WIDTH					
OB.HT.	100	120	140	160	180	200
30	1.66	1.64	1.63	1.63	1.68	1.76
50	2.84	2.77	2.74	2.74	2.74	2.74
70	4.12	4.07	4.02	3.97	3.97	3.92
90*	5.67	5.67	5.58	5.58	5.58	5.67**
110**	10.64	10.10	9.83	9.50	9.35	9.24
130**	19.06	16.45	15.11	14.02	13.41	12.56

* Side casting with 20 ft. chop down
** Extended bench with 20 ft. chop down

TOTAL COST PER CUBIC YARD OF OVERBURDEN REMOVED ($/LCY):

	PIT WIDTH					
OB.HT.	100	120	140	160	180	200
30	0.16	0.16	0.16	0.16	0.16	0.17
50	0.16	0.16	0.16	0.16	0.16	0.16
70	0.17	0.17	0.17	0.16	0.16	0.16
90*	0.18	0.18	0.18	0.18	0.18	0.19**
110**	0.20	0.20	0.20	0.20	0.20	0.20
130**	0.21	0.21	0.21	0.20	0.20	0.20

TABLE 25 : MARION 8200-21R
DRAGLINE WEIGHTED ANNUAL LIGNITE PRODUCTION
COMPARISON FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT RESERVE IN INCREMENT	100 FT. PIT WIDTH		120 FT. PIT WIDTH		140 FT. PIT WIDTH	
		PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)	PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)	PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)
20 - 40	16.3	2327	379	2369	386	2410	393
40 - 60	17.3	1346	233	1396	241	1421	246
60 - 80	25.0	908	227	926	231	944	236
80 - 100	18.5	637	118	637	118	651	120
100 - 120	16.2	380	62	403	65	413	67
120 - 140	6.7	209	14.0	244	17	265	18
Average Production (Tons/Year)			1033		1058		1080

TABLE 25: MARION 8200-21R
DRAGLINE WEIGHTED ANNUAL LIGNITE PRODUCTION
COMPARISON FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT RESERVE IN INCREMENT	160 FT. PIT WIDTH PRODUCTION (TONS/YR)	160 FT. PIT WIDTH WEIGHTED PROD. (TONS/YR)	180 FT. PIT WIDTH PRODUCTION (TONS/YR)	180 FT. PIT WIDTH WEIGHTED PROD. (TONS/YR)	200 FT. PIT WIDTH PRODUCTION (TONS/YR)	200 FT. PIT WIDTH WEIGHTED PROD. (TONS/YR)
20 - 40	16.3	2410	393	2286	373	2119	345
40 - 60	17.3	1421	246	1421	246	1421	246
60 - 80	25.0	962	240	962	240	980	245
80 - 100	18.5	651	120	651	120	637	118
100 - 120	16.2	430	70	437	71	443	72
120 - 140	6.7	288	19	301	20	318	21
Average Production (Tons/Year)			1088		1070		1047

TABLE 25 : MARION 8200-21R
DRAGLINE WEIGHTED HOURLY OVERBURDEN
PRODUCTION COMPARISON FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT RESERVES IN INCREMENT	100 FT. PIT WIDTH		120 FT. PIT WIDTH		140 FT. PIT WIDTH	
		PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)
20 - 40	16.3	2922	476	2973	485	3026	493
40 - 60	17.3	2817	487	2922	505	2974	514
60 - 80	25.0	2661	665	2713	678	2765	691
80 - 100	18.5	2400	444	2400	444	2452	454
100 - 120	16.2	2399	389	2452	397	2452	397
120 - 140	6.7	2296	154	2342	157	2347	157
Average Hourly Production (BCY/HOUR)			2615		2666		2706

TABLE 25 : MARION 8200-21R
DRAGLINE WEIGHTED HOURLY OVERBURDEN
PRODUCTION COMPARISON FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT RESERVES IN INCREMENT	160 FT. PIT WIDTH PRODUCTION RATE (BCY/HOUR)	160 FT. PIT WIDTH WEIGHTED PROD. (BCY/HOUR)	180 FT. PIT WIDTH PRODUCTION RATE (BCY/HOUR)	180 FT. PIT WIDTH WEIGHTED PROD. (BCY/HOUR)	200 FT. PIT WIDTH PRODUCTION RATE (BCY/HOUR)	200 FT. PIT WIDTH WEIGHTED PROD. (BCY/HOUR)
20 - 40	16.3	3026	493	2865	467	2660	434
40 - 60	17.3	2974	514	2974	514	2974	514
60 - 80	25.0	2817	704	2817	704	2869	717
80 - 100	18.5	2452	453	2452	454	2400	444
100 - 120	16.2	2504	406	2504	406	2504	406
120 - 140	6.7	2400	161	2400	161	2452	164
Average Hourly Production (BCY/HOUR)			2731		2706		2679

TABLE 25 : MARION 8200-21R
DRAGLINE WEIGHTED COST COMPARISON
FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT LIGNITE IN INCREMENT	100 FT. PIT WIDTH				120 FT. PIT WIDTH				140 FT. PIT WIDTH			
		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)	
		OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.
20 - 40	16.3	0.92	0.74	0.15	0.12	0.91	0.74	0.15	0.12	0.89	0.73	0.14	0.12
40 - 60	17.3	1.60	1.24	0.28	0.21	1.54	1.23	0.27	0.21	1.51	1.23	0.26	0.21
60 - 80	25.0	2.37	1.75	0.59	0.44	2.32	1.74	0.58	0.43	2.28	1.74	0.57	0.43
80 - 100	18.5	3.37	2.29	0.62	0.42	3.37	2.29	0.62	0.42	3.30	2.28	0.61	0.42
100 - 120	16.2	5.66	4.97	0.92	0.81	5.34	4.75	0.87	0.77	5.20	4.63	0.84	0.75
120 - 140	6.7	10.28	8.78	0.69	0.59	8.82	7.64	0.59	0.51	8.10	7.02	0.54	0.47
Average Ownership & Operating Cost ($/Ton)				3.25	2.59			3.08	2.46			2.96	2.40

TABLE 25 : MARION 8200-21R
DRAGLINE WEIGHTED COST COMPARISON
FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT LIGNITE IN INCREMENT	160 FT. PIT WIDTH				180 FT. PIT WIDTH				200 FT. PIT WIDTH			
		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)	
		OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.
20 - 40	16.3	0.89	0.73	0.14	0.12	0.94	0.74	0.15	0.12	1.01	0.75	0.16	0.12
40 - 60	17.3	1.51	1.23	0.26	0.21	1.51	1.23	0.26	0.21	1.51	1.23	0.26	0.21
60 - 80	25.0	2.24	1.73	0.56	0.43	2.24	1.73	0.56	0.43	2.13	1.73	0.55	0.43
80 - 100	18.5	3.30	2.28	0.61	0.42	3.30	2.28	0.61	0.42	3.37	2.29	0.62	0.42
100 - 120	16.2	4.99	4.51	0.81	0.73	4.92	4.44	0.80	0.72	4.86	4.38	0.79	0.71
120 - 140	6.7	7.46	6.56	0.50	0.44	7.14	6.27	0.48	0.42	6.75	6.01	0.45	0.40
Average Ownership & Operating Cost ($/Ton)				2.88	2.35			2.98	2.42			3.21	2.48

MARION 8050-23A

AVERAGE SWING ANGLE (DEGREES):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	44.37	45.22	48.86	52.65	89.67	104.20
50	52.97	55.19	58.41	58.75	61.52	99.68
70	65.48	68.01	69.14	70.96	73.08	73.93
90*	96.46	98.02	98.74	100.56	129.82***	128.90***
110**	100.75	97.77	95.64	93.82	92.08	90.99
130**	130.58	127.37	123.96	121.64	119.55	116.41

* Side casting with 20 ft. chop down
** Extended bench with 20 ft. chop down
*** Extended bench with 0.0 ft. chop down

AVERAGE CYCLE TIME (SECONDS):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	63.09	61.68	61.08	61.60	67.76	70.19
50	65.19	63.76	63.01	62.26	62.22	69.74
70	69.75	68.08	67.54	66.69	66.60	66.00
90*	77.83	76.82	76.21	75.72	75.77***	75.12***
110**	77.14	76.07	75.49	74.94	74.50	73.29
130**	80.83	79.88	79.18	77.99	77.01	76.44

MARION 8050-23A

PRODUCTION RATE (BCY/HR):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	2486	2529	2529	2529	2311	2223
50	2398	2442	2486	2486	2486	2224
70	2224	2267	2361	2361	2355	2355
90*	2006	2006	2049	2049	2049.51***	2049.51***
110**	2006	2049	2049	2093	2093	2136
130**	1919	1962	1962	2006	2006	2049

* Side casting with 20 ft. chop down
** Extended bench with 20 ft. chop down
*** Extended bench with 0.0 ft. chop down

TONS OF COAL MINED PER YEAR (10^3 T/YR):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	1980	2015	2015	2015	1841	1771
50	1146	1167	1188	1188	1188	1063
70	759	774	789	789	804	804
90*	533	533	544	544	447***	450***
110**	298	321	332	349	356	369
130**	163	193	213	233	245	261

MARION 8050-23A

OWNERSHIP COST PER TON RECOVERED ($/TON):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	0.94	0.93	0.93	0.93	1.02	1.06
50	1.63	1.60	1.57	1.57	1.57	1.76
70	2.46	2.42	2.37	2.37	2.33	2.33
90*	3.51	3.51	3.44	3.44	4.18***	4.16***
110**	6.27	5.83	5.62	5.36	5.25	5.06
130**	11.48	9.66	8.77	8.01	7.62	7.17

* Side casting with 20 ft. chop down
** Extended bench with 20 ft. chop down
*** Extended bench with 0.0 ft. chop down

OPERATING COST PER TON RECOVERED ($/TON):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	0.76	0.76	0.76	0.76	0.77	0.77
50	1.27	1.27	1.26	1.26	1.26	1.29
70	1.81	1.80	1.79	1.79	1.79	1.79
90*	2.37	2.37	2.36	2.36	3.63***	3.61***
110**	5.36	5.06	4.88	4.71	4.61	4.51
130**	9.56	8.16	7.40	6.86	6.52	6.22

MARION 8050-23A

TOTAL COST PER TON OF COAL RECOVERED ($/TON):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	1.70	1.68	1.68	1.68	1.78	1.83
50	2.90	2.87	2.84	2.84	2.84	3.05
70	4.27	4.22	4.16	4.16	4.11	4.11
90*	5.88	5.88	5.80	5.80	7.81***	7.77***
110**	11.63	10.88	10.50	10.08	9.86	9.57
130**	21.04	17.82	16.17	14.87	14.14	13.40

* Side casting with 20 ft. chop down
** Extended bench with 20 ft. chop down
*** Extended bench with 0.0 ft. chop down

TOTAL COST PER CUBIC YARD OF OVERBURDEN REMOVED ($/LCY):

PIT WIDTH

OB.HT.	100	120	140	160	180	200
30	0.16	0.16	0.16	0.16	0.17	0.18
50	0.17	0.17	0.16	0.16	0.16	0.18
70	0.18	0.17	0.17	0.17	0.17	0.17
90*	0.19	0.19	0.19	0.19	0.21***	0.21***
110**	0.21	0.21	0.21	0.20	0.20	0.20
130**	0.22	0.21	0.21	0.21	0.21	0.21

Table 26: MARION 8050-23A
DRAGLINE WEIGHTED HOURLY OVERBURDEN
PRODUCTION COMPARISON FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT RESERVES IN INCREMENT	100 FT. PIT WIDTH		120 FT. PIT WIDTH		140 FT. PIT WIDTH	
		PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)
20 - 40	16.3	2486	405	2529	412	2529	412
40 - 60	17.3	2398	415	2442	422	2486	430
60 - 80	25.0	2224	556	2267	566	2361	590
80 - 100	18.5	2006	371	2006	371	2049	379
100 - 120	16.2	2006	325	2045	332	2049	332
120 - 140	6.7	1919	129	1962	131	1562	131
Average Hourly Production (BCY/HOUR)			2201		2234		2274

TABLE 26: MARION 8050-23A
DRAGLINE WEIGHTED HOURLY OVERBURDEN
PRODUCTION COMPARISON FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT RESERVES IN INCREMENT	160 FT. PIT WIDTH		180 FT. PIT WIDTH		200 FT. PIT WIDTH	
		PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)	PRODUCTION RATE (BCY/HOUR)	WEIGHTED PROD. (BCY/HOUR)
20 - 40	16.3	2529	412	2311	377	2223	362
40 - 60	17.3	2486	430	2486	430	2224	385
60 - 80	25.0	2361	590	2355	589	2355	589
80 - 100	18.5	2049	379	2049	379	2045	379
100 - 120	16.2	2093	339	2093	339	2136	346
120 - 140	6.7	2006	134	2006	134	2049	137
Average Hourly Production (BCY/HOUR)			2284		2248		2198

TABLE 26: MARION 8050-23A
DRAGLINE WEIGHTED ANNUAL LIGNITE PRODUCTION
COMPARISON FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT RESERVE IN INCREMENT	100 FT. PIT WIDTH PRODUCTION (TONS/YR)	100 FT. PIT WIDTH WEIGHTED PROD. (TONS/YR)	120 FT. PIT WIDTH PRODUCTION (TONS/YR)	120 FT. PIT WIDTH WEIGHTED PROD. (TONS/YR)	140 FT. PIT WIDTH PRODUCTION (TONS/YR)	140 FT. PIT WIDTH WEIGHTED PROD. (TONS/YR)
20 - 40	16.3	1980	323	2015	328	2015	328
40 - 60	17.3	1146	198	1167	201	1188	205
60 - 80	25.0	759	190	774	199	789	197
80 - 100	18.5	533	98	533	98	544	101
100 - 120	16.2	298	48	321	52	332	54
120 - 140	6.7	163	11	193	13	213	15
Average Production (Tons/Year)			868		891		900

TABLE 26: MARION 8050-23A
DRAGLINE WEIGHTED ANNUAL LIGNITE PRODUCTION
COMPARISON FOR VARIOUS PIT WIDTHS

		160 FT. PIT WIDTH		180 FT. PIT WIDTH		200 FT. PIT WIDTH	
OVERBURDEN INCREMENT	PERCENT RESERVE IN INCREMENT	PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)	PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)	PRODUCTION (TONS/YR)	WEIGHTED PROD. (TONS/YR)
20 - 40	16.3	2015	328	1841	296	1771	289
40 - 60	17.3	1188	205	1188	205	1063	184
60 - 80	25.0	789	197	804	201	804	201
80 - 100	18.5	544	101	447	83	450	83
100 - 120	16.2	349	56	356	58	369	60
120 - 140	6.7	233	16	245	17	261	18
Average Production (Tons/Year)			903		860		835

TABLE 26: MARION 8050-23A
DRAGLINE WEIGHTED COST COMPARISON
FOR VARIOUS PIT WIDTHS

OVERBURDEN INCREMENT	PERCENT LIGNITE IN INCREMENT	100 FT. PIT WIDTH				120 FT. PIT WIDTH				140 FT. PIT WIDTH			
		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)	
		OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.
20 - 40	16.3	0.94	0.76	0.15	0.12	0.93	0.76	0.15	0.12	0.53	0.76	0.15	0.12
40 - 60	17.3	1.63	1.27	0.28	0.22	1.60	1.27	0.28	0.22	1.57	1.26	0.27	0.22
60 - 80	25.0	2.46	1.81	0.62	0.45	2.42	1.80	0.60	0.45	2.37	1.79	0.59	0.45
80 - 100	18.5	3.51	2.37	0.65	0.44	3.51	2.37	0.65	0.44	3.44	2.36	0.64	0.44
100 - 120	16.2	6.27	5.36	1.01	0.87	5.83	5.06	0.94	0.82	5.62	4.88	0.91	0.79
120 - 140	6.7	11.48	9.56	0.77	0.64	9.66	8.16	0.65	0.55	8.77	7.40	0.59	0.49
Average Ownership & Operating Cost ($/Ton)				3.48	2.74			3.27	2.60			3.15	2.51

TABLE 26: MARION 8050-23A
DRAGLINE WEIGHTED COST COMPARISON
FOR VARIOUS PIT WIDTHS

		160 FT. PIT WIDTH				180 FT. PIT WIDTH				200 FT. PIT WIDTH			
		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)		DRAGLINE COST ($/T LIGNITE)		WEIGHTED COST ($/T LIGNITE)	
OVERBURDEN INCREMENT	PERCENT LIGNITE IN INCREMENT	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.	OWN.	OP.
20 - 40	16.3	0.93	0.76	0.15	0.12	1.02	0.77	1.17	0.12	1.06	0.77	0.17	0.12
40 - 60	17.3	1.57	1.26	0.27	0.72	1.57	1.26	0.27	0.22	1.76	1.29	0.30	0.22
60 - 80	25.0	2.37	1.79	0.59	0.45	2.33	1.79	0.58	0.45	2.33	1.79	0.58	0.45
80 - 100	18.5	3.44	2.36	0.64	0.44	4.18	3.63	0.77	0.67	4.16	3.61	0.77	0.67
100 - 120	16.2	5.36	4.71	0.87	0.76	5.25	4.61	0.85	0.75	5.06	4.51	0.82	0.73
120 - 140	6.7	8.01	6.86	0.54	0.46	7.12	6.52	0.48	0.44	7.17	6.22	0.48	0.42
Average Ownership & Operating Cost ($/Ton)				3.06	2.45			3.12	2.65			3.12	2.61

APPENDIX F

List of Computer Codes

Select. For

Side. For

Ext. For

Pul 1. For

Pul 2. For

```
*****************************************************************
C
C      THIS IS THE COMPUTER PROGRAM TO SELECT A DRAGLINE
C      FOR A STRIPPING OPERATION
C      PROGRAMED BY KADRI DAGDELEN
C      PROGRAM NAME: SELECT.FOR
C
******************************************************************
C
       DIMENSION DDFDF(0/15),DDFH(0/15),DTXS(15,0/30),TVS(0/15)
       DIMENSION UV(0/15,0/30),VOL(0/15),ASA(15),TT(15)
       DIMENSION WD(15),WT(15),UVT(30),WSA(15)
       REAL JF
C
C      INITIALIZE VARIABLES
       DATA TVSFK,TVSFP,JTVSFP,TVSS,TWSA,TWD/6*0.0/,TVS/16*0.0/
       DATA UV/496*0.0/,VOL(0)/0.0/,CONV/57.2957/,UVT/30*0.0/
       DATA WSA/15*0.0/
******************************************************************
C                      INPUT  DATA
       OPEN(UNIT=8,FILE='SELECT.DAT',ACCESS='SEQIN')
       READ(8,100)H,CT,A,B,C,FA,SF,X,W,WK
100    FORMAT(10F)
       READ(8,120)CABHT,CABRAD,P
120    FORMAT(3F)
       READ(8,150)DT,BPT,ST1,ST2,SCC,WS,CLT
150    FORMAT(7F)
       READ(8,160)AP,SH,AV,JF,FF
160    FORMAT(5F)
       READ(8,130)NPK,NTP,N
130    FORMAT(3I)
       READ(8,140)(DDFDF(J),DDFH(J),J=1,NTP)
140    FORMAT(2F)
       READ(8,171)IFLAG
171    FORMAT(I)
       IF(IFLAG.EQ.0)GO TO 174
       READ(8,172)NFSIKP,NFSLKP,NFSTP
172    FORMAT(3I)
       READ(8,173)(DDFDF(J),DDFH(J),J=NFSIKP,NFSTP)
173    FORMAT(2F)
174    IF(IFLAG.EQ.0)NFSTP=NTP
       IF(IFLAG.EQ.1)GO TO 176
       TOPKEY=(H/TAND(A))*2.+WK
       IF(TOPKEY.GE.W-5.)WRITE(4,175)
175    FORMAT(1X,10X,'OVERBURDEN IS TOO DEEP',/
      1  1X,10X,'IT WILL BE MINED IN TWO LIFTS',/
      1  1X,10X,'ENTER NEW SET OF DRAGLINE ',/
      1  1X,10X,'POSITIONS FOR SECOND LIFT')
       STOP
176    UIL=X/FLOAT(N)
       DO 70 I=1,NFSTP
```

```
      DTXS(I,0)=DDFDF(I)-P+X+UIL/2.
70    CONTINUE
      DDFH(0)=DDFH(NTP)
      DDFDF(0)=-X+DDFDF(NTP)
      SF=1.0+SF/100.
C
C     CALCULATE REQUIRED DRAGLINE REACH
C
      ODR=H/TAND(A)+CT/TAND(C)+H*(SF)/TAND(B)+W/4.0+P
      DOR=X*X/(4.0*ODR)+ODR
C
C
      JM=1
      M=0
      MI=NPK
      JI=NTP
177   IF((IFLAG.EQ.1).AND.(M.EQ.JI))JM=NFSIKP
      IF((IFLAG.EQ.1).AND.(M.EQ.JI))NTP=NFSTP
      IF((IFLAG.EQ.1).AND.(M.EQ.JI))NPK=NFSLKP
      DO 75 K=JM,NTP
      M=K
      IF(K.GT.NPK) GO TO 20
      COK=DDFH(K)-(W-TOPKEY/2.)
      SAA=ATAN(COK/DDFDF(K))*CONV
      RK=1.5
      TVS(JI)=0.0
      TVSFK=TVSFK+TVS(K-1)
      CALL VOLKEY(DDFDF(K),A,FA,CABHT,CABRAD,H,X,WK,IFLAG
     1  ,VOL(K))
      VOL(K)=VOL(K)*SF
      VOL(K)=VOL(K)-TVSFK
      GO TO 30
      COM=DDFH(K)-(W-TOPKEY)/2.
      SAA=ATAN(COM/DDFDF(K))*CONV
20    RK=1.0
      TVS(NPK)=0.0
      CALL VOLCUT(DDFDF(K),A,FA,CABHT,CABRAD,H,X,W,WK,IFLAG,
     1  VOL(K))
      VOL(K)=VOL(K)*SF
      TVSFP=TVSFP+TVS(K-1)
      VOL(K)=VOL(K)-TVSFP
30    DO 50 J=1,N
      DTXS(K,J)=DTXS(K,J-1)-UIL
      SA=ACOS(DTXS(K,J)/DOR)*CONV-SAA
      UVT(J)=UV(K-1,J)+UVT(J)
      CONST1=W*TAND(B)*UIL
      CONST2=H/TAND(A)+W/4.0
      CONST3=SQRT(DOR*DOR-DTXS(K,J)*DTXS(K,J))-DDFH(K)
      UV(K,J)=CONST1*(CONST3-CONST2)-UVT(J)
      IF(UV(K,J).LE.(VOL(K)-TVS(K))) GO TO 40
      UV(K,J)=VOL(K)-TVS(K)
```

```
40     WSA(K)=WSA(K)+SA*UV(K,J)
       TVS(K)=TVS(K)+UV(K,J)
       IF(TVS(K).EQ.VOL(K)) GO TO 60
50     CONTINUE
60     IF(TVS(K).NE.0.0)ASA(K)=WSA(K)/TVS(K)
65     WD(K)=SQRT((DDFDF(K)-DDFDF(K-1))**2+(DDFH(K)-DDFH(K-1))*
      1  *2)
       TWD=TWD+WD(K)
       TVSS=TVSS+TVS(K)
       TWSA=TWSA+WSA(K)
75     CONTINUE
       TVSFK=0.0
       TVSFP=0.0
       IF((IFLAG.EQ.1).AND.(M.EQ.JI))GO TO 177
       FASA=TWSA/TVSS
       SM=(ST2-ST1)/30.0
       AST=FASA*SM+SCC
       ACT=(AST+DT+BPT)*RK
       BC=(AP*SF*ACT)/(SH*AV*JF*3600.0)
       TNOC=TVSS/(BC*27.)
       TCT=TNOC*ACT
       TWT=TWD/WS+NTP*CLT
       TTSS=TCT+TWT
       ACT=TTSS/TNOC
       BC=(AP*SF*ACT)/(FF*SH*AV*JF*3600.)
       WRITE(4,240)DDR,BC,FASA,ACT,AP
240    FORMAT(1X,10X,'REQUIRED DRAGLINE REACH :',F10.2,2X,'FT'/
      1  1X,10X,'BUCKET CAPACITY',9X,':',F10.2,2X,'CU YD'/
      1  1X,10X,'AVERAGE SWING ANGLE',5X,':',F10.2,2X,'DEGREES'/
      1  1X,10X,'AVERAGE CYCLE TIME'6X,':',F10.2,2X,'SECONDS'/
      1  1X,10X,'ANNUAL PRODUCTION',7X,':',F10.1,2X,'BCY')
       WRITE(4,250)H,CT,A,B,C,W,X
250    FORMAT(//,2X,29X,'FOR'//
      1  1X,10X,'OVERBURDEN HEIGHT',7X,':',F10.2,2X,'FT'/
      1   1X,10X,'COAL THICKNESS',10X,':',F10.2,2X,'FT'/
      1  1X,10X,'HIGHWALL ANGLE OF REPOSE:',F10.2,2X,'DEGREES'/
      1  1X,10X,'SPOIL ANGLE OF REPOSE',3X,':',F10.2,2X,'DEGREES'
      1  /1X,10X,'COAL ANGLE OF REPOSE',4X,':'F10.2,2X,'DEGREES'/
      1  1X,10X,'PIT WIDTH',15X,':',F10.2,2X,'FT'/
      1  1X,10X'CUT LENGTH',14X,':',F10.2,2X,'FT')
       END
```

```
      SUBROUTINE VOLKEY(DLDIST,A,FA,CABHT,CABRAD,H,CUT,BOTKEY
     1  ,IFLAG,VOL)
      DEPTH=H
      IF(IFLAG.EQ.1)DEPTH=DEPTH/2.
      THTAN=TAND(FA)
      DIGTAN=CABHT/(DLDIST-CABRAD)
      OF=DLDIST+CUT+DEPTH/THTAN
      OJ=DEPTH/TAND(FA)
      XBROW=OJ
      XINT=OF-CABRAD-((DEPTH+CABHT)/DIGTAN)
      IF(XINT.GT.CUT)XINT=CUT
      UHT=CUT*DIGTAN
      IF(UHT.GT.DEPTH)UHT=DEPTH
      LHT=DEPTH-UHT
      TOPKEY=(DEPTH/TAND(A))*2.0+BOTKEY
      MIDKEY=BOTKEY+(LHT/DEPTH)*(TOPKEY-BOTKEY)
      C=-XINT*DIGTAN
      BXLONG=DEPTH/THTAN-C/(THTAN-DIGTAN)
      IF(XINT.LE.0.0) GO TO 10
      IF(XINT.LE.OJ)GO TO 11
      IF(XINT.GE.OJ)GO TO 12
10    VOL=(BXLONG+CUT)*UHT*(TOPKEY+MIDKEY)/4.0
      GO TO 13
11    VOL=CUT*UHT*(TOPKEY+MIDKEY)/4.+((DEPTH**2)
     1  *(TOPKEY+BOTKEY))/(4.0*THTAN)-(XBROW-XINT)
     1  *LHT*((BOTKEY+MIDKEY)/4.0)
      GO TO 13
12    AREA=DEPTH*(TOPKEY+BOTKEY)/2.0
      XBROW=OJ
      VOL=(XBROW+CUT-XINT)*AREA/2.0+(XINT-XBROW)*AREA+
     1  XBROW*AREA/2.0
13    RETURN
      END
```

```
      SUBROUTINE VOLCUT(DLDIST,A,FA,CABHT,CABRAD,H,CUT,W,
     1  BOTKEY,IFLAG,VOL)
      DEPTH=H
      IF(IFLAG.EQ.1)DEPTH=DEPTH/2.
      THTAN=TAND(FA)
      DIGTAN=CABHT/(DLDIST-CABRAD)
      OF=DLDIST+CUT+DEPTH/THTAN
      OJ=DEPTH/TAND(FA)
      XINT=OF-CABRAD-((DEPTH+CABHT)/DIGTAN)
      IF(XINT.GT.CUT)XINT=CUT
      XBROW=OJ
      UHT=CUT*DIGTAN
      IF(UHT.GT.DEPTH)UHT=DEPTH
      LHT=DEPTH-UHT
      TOPKEY=(DEPTH/TAND(A))*2.0+BOTKEY
      MIDKEY=BOTKEY+(LHT/DEPTH)*(TOPKEY-BOTKEY)
      WIDTH=W-TOPKEY
      C=-XINT*DIGTAN
      BXLONG=DEPTH/THTAN-C/(THTAN-DIGTAN)
      IF(XINT.LE.0)GO TO 10
      IF(XINT.LE.OJ) GO TO 11
      IF(XINT.GT.OJ)GO TO 12
10    Z1ARE1=UHT*CUT/2.
      Z1ARE2=UHT*BXLONG/2.
      Z1TVOL=(Z1ARE1+Z1ARE2)*WIDTH
      XSIDE=UHT**2.*XBROW/(2*DEPTH)
      Z2TVOL=XSIDE*(CUT+BXLONG)/2.0
      VOL=Z1TVOL+2.*Z2TVOL
      RETURN
11    Z1ARE1=UHT*CUT/2.
      Z1AR23=DEPTH*OJ/2.
      Z1ARE3=(DEPTH-UHT)*(XBROW-XINT)/2.0
      Z1VOL=(Z1ARE1+Z1AR23-Z1ARE3)*WIDTH
      XSIDE=UHT**2/(2.*TAND(A))
      Z2VOL1=XSIDE*CUT/2.0
      TXSIDE=DEPTH**2./(2.*TAND(A))
      Z2VOL2=TXSIDE*XBROW/2.
      Z2VOL3=(TXSIDE-XSIDE)*(XBROW-XINT)/2.
      Z2TVOL=Z2VOL1+Z2VOL2-Z2VOL3
      VOL=Z1VOL+2.*Z2TVOL
      RETURN
12    Z1ARE1=DEPTH*(XBROW+CUT-XINT)/2.
      Z1ARE2=DEPTH*(XINT-XBROW)
      Z1ARE3=DEPTH*(XBROW)/2.0
      Z1TVOL=(Z1ARE1+Z1ARE2+Z1ARE3)*WIDTH
      XSIDE=DEPTH*XBROW/2.
      Z2VOL1=XSIDE*(XBROW+CUT-XINT)/2.
      Z2VOL2=XSIDE*(XINT-XBROW)
      Z2VOL3=XSIDE*XBROW/2.
      Z2TVOL=Z2VOL1+Z2VOL2+Z2VOL3
      VOL=Z1TVOL+2.*Z2TVOL
```

```
      RETURN
      END
```

```
C      THIS IS THE COMPUTER PROGRAM TO CALCULATE PRODUCTION OF A DRAGLINE
C      TO SIMULATE ITS SIDE CASTING OPERATION.

C      PROGRAM NAME : SIDE.FOR
C      PROGRAMED BY KADRI DAGDELEN
C
       DIMENSION DDFDF(0/15),DDFH(0/15),DTXS(15,0/30),TVS(0/15)
     1  ,UV(0/15,0/30),VOL(0/15),ASA(15),TT(15),TCT(15),WD(15),
     1  WT(15),UVT(30),WSA(15),HYPHEN(15),AS(30),CDSA(30)
       REAL ITIP,LR,LCH,MCH,JF
       INTEGER TNOC
       DOUBLE PRECISION MT,HYPHEN
C
C      INITIALIZE VARIABLES
C
       DATA TTSFP,TTSFK/2*0.0/,TVSS,TTSS/2*0.0/,TVS/16*0.0/
     1  ,VOL(0)/0.0/,CONV/57.2957/,TVSFK,TVSFP,TCTE/3*0.0/
     1  ,UVT/30*0.0/,WSA/15*0.0/,UV/496*0.0/,TWSA,TOTCT,
     1  TOTWT/3*0.0/,HYPHEN/15*'----------'/
       OPEN(UNIT=8,FILE='SIDE.DAT',ACCESS='SEQIN')
       KY=6
       READ(8,100)H,W,CT,CD,A,B,C,FA,SF,X,WK
100    FORMAT(11F)
       READ(8,105)CDBH
105    FORMAT(F)
       READ(8,106)XD,YD
106    FORMAT(2F)
       READ(8,110)MT
110    FORMAT(A10)
       READ(8,120)DR,BC,CABHT,CABRAD,P
120    FORMAT(5F)
       READ(8,150)DT,BPT,ST1,ST2,SCC,WS,CLT
150    FORMAT(7F)
       READ(8,160)SH,AV,JF,RF,FF
160    FORMAT(5F)
       READ(8,170)DIC,PCKH,PCH,LR,DOL,CRF,ITIP
170    FORMAT(7F)
       READ(8,130)NPK,NTP,N
130    FORMAT(3I)
       READ(8,140)(DDFDF(J),DDFH(J),J=1,NTP)
140    FORMAT(2F)
       READ(8,171)IFLAG
171    FORMAT(I)
       IF(IFLAG.EQ.0)GO TO 174
       READ(8,172)NFSIKP,NFSLKP,NFSTP
172    FORMAT(3I)
       READ(8,173)(DDFDF(J),DDFH(J),J=NFSIKP,NFSTP)
173    FORMAT(2F)
174    IF(IFLAG.EQ.0)NFSTP=NTP
       DDFH(0)=DDFH(NTP)
       DDFDF(0)=-X+DDFDF(NTP)
```

```
      SF=1.0+SF/100.
      BC=BC*FF*27
      CDVOL=0.0
      TVRH=0.0
      PRCRH=0.0
      DEPTH=H
C
C     CALCULATE REQUIRED DRAGLINE REACH
      IF(CDBH.EQ.0.0)GO TO 31
      HE=CDBH/TAND(A)
      SRG=W*CDBH*TAND(B)/TAND(A)
      HG=SRG/(W*SF)
      H=H-HG
31    ODR=H/TAND(A)+CT/TAND(C)+H*(SF)/TAND(B)+W/4.0+P
      DOR=X*X/(4.0*ODR)+ODR
C
C
C       CHECK IF DRAGLINE REACH IS ADEQUATE FOR SIDE CASTING
      IF(DOR.LT.DR+3) GO TO 10
      WRITE(4,600)
600   FORMAT(19X,'DRAGLINE REACH IS INSUFFICIENT'/,19X,
     1 'USE ONE OF THE  FOLLOWING METHODS'/
     1 1X,22X,'A)',1X,'EXTENDED BENCH',/23X,'B)',1X,'EXTENDED'
     1 ,' BENCH WITH CHOP DOWN',/1X,22X,'C)',1X,'PULL BACK')
      STOP
      H=DEPTH-CDBH
10    IF(IFLAG.EQ.1)GO TO 11
      TOPKEY=(H/TAND(A))*2.+WK
      IF (TOPKEY.LE.W-5.)GO TO 11
      WRITE(4,175)
175   FORMAT(1X,10X,'OVERBURDEN IS TOO DEEP',/
     1 1X,10X,'IT WILL BE MINED IN TWO LIFTS',/
     1 1X,10X,'ENTER NEW SET OF DRAGLINE ',/
     1 1X,10X,'POSITIONS FOR SECOND LIFT')
      STOP
C
C     CALCULATE VOLUME REMOVED FROM EACH POSITION
C
11    UIL=X/FLOAT(N)
      T2=(DOR*DOR-X*X)
      DFXS=SQRT(DR*DR-T2)-P
      IF(DFXS.GT.X-P+3)GO TO 16
      DO 15 I=1,NFSTP
      DTXS(I,0)=DDFDF(I)-P+X+UIL/2.
15    CONTINUE
      GO TO 18
C   SHALLOW OVERBURDEN CASE
16    DO 17 I=1,NFSTP
      DTXS(I,0)=DFXS-P+DDFDF(I)+UIL/2.
17    CONTINUE
18    IF(CDBH.EQ.0.0)GO TO 29
```

```
      H=DEPTH-CDBH
      IF(XD.LE.DDFH(1))XD1=DDFH(1)-XD
      IF(XD.GT.DDFH(1))XD1=XD-DDFH(1)
      IF(YD.LT.DDFDF(1))YD1=DDFDF(1)-YD
      IF(YD.GT.DDFDF(1))YD1=YD-DDFDF(1)
      IF((XD.GT.DDFH(1)).AND.(YD.LT.DDFDF(1)))GO TO 21
      IF((XD.LT.DDFH(1)).AND.(YD.GT.DDFDF(1)))GO TO 22
      IF((XD.GT.DDFH(1)).AND.(YD.GT.DDFDF(1)))GO TO 23
21    CDASA=ATAN(XD1/YD1)*CONV
      GO TO 24
22    CDASA=ATAN(YD1/XD1)*CONV
      GO TO 24
23    CDASA=ATAN(YD1/XD1)*CONV+90.
24    DO 27 K=1,1
      CDVOL=(CDBH*X*W)*SF
      TVSS=CDVOL
      DO 26 J=1,N
      DTXS(K,J)=DTXS(K,J-1)-UIL
      AS(J)=ACOS(DTXS(K,J)/DR)*CONV
      CONST1=W*TAND(B)*UIL
      CONST2=H/TAND(A)+W/4.
      CONST3=SQRT(DR*DR-DTXS(K,J)*DTXS(K,J))-DDFH(K)
      UV(K,J)=CONST1*(CONST3-CONST2)-UVT(J)
      IF(UV(K,J).LE.(CDVOL-TVS(1)))GO TO 25
      UV(K,J)=CDVOL-TVS(1)
25    UVT(J)=UV(K,J)
      WSA(K)=WSA(K)+AS(J)*UV(K,J)
      TVS(K)=TVS(K)+UV(K,J)
      IF(TVS(K).EQ.CDVOL)GO TO 28
26    CONTINUE
28    CDSA(1)=WSA(1)/TVS(1)
      IF((XD.LT.DDFH(1)).AND.(YD.GT.DDFDF(1)))CDSA(1)=180.-CDSA(1)-2.*CD
      CDSA(1)=CDSA(1)+CDASA
      IF((XD.GT.DDFH(1)).AND.(YD.GT.DDFDF(1)))CDSA(1)=360.-CDSA(1)
      WSA(1)=CDSA(1)*CDVOL
27    CONTINUE
      H=DEPTH-CDBH
      TVS(1)=0.0
      TVSS=CDVOL
29    JM=1
      M=0
      MI=NPK
      JI=NTP
      TOPKEY=(H/TAND(A))*2.+WK
      IF(IFLAG.EQ.1)TOPKEY=(H/TAND(A))+WK
177   IF((IFLAG.EQ.1).AND.(M.EQ.JI))JM=NFSIKP
      IF((IFLAG.EQ.1).AND.(M.EQ.JI))NTP=NFSTP
      IF((IFLAG.EQ.1).AND.(M.EQ.JI))NPK=NFSLKP
      DO 70 K=JM,NTP
      M=K
C
```

```
C      CHECK WHETHER DRAGLINE IS IN KEY CUT
C
       IF(K.GT.NPK) GO TO 20
C
C
C      DRAGLINE IS IN KEY CUT POSTION; CALCULATE VOLUME REMOVEABLE
C
       COK=DDFH(K)-(W-TOPKEY/2.)
       SAA=ATAN(COK/DDFDF(K))*CONV
       RK=1.5
       TVS(JI)=0.0
       TVSFK=TVSFK+TVS(K-1)
       CALL VOLKEY(DDFDF(K),A,FA,CABHT,CABRAD,H,X,WK,IFLAG,
      1  VOL(K))
       VOL(K)=VOL(K)*SF
       VOL(K)=VOL(K)-TVSFK
       TVSLKP=VOL(MI)
       VSFFKP=VOL(NPK)
       GO TO 30
C
C      IN PRIME CUT POSITION; CALCULATE VOLUME REMOVABLE
C
       COM=DDFH(K)-(W-TOPKEY)/2.
       SAA=ATAN(COM/DDFDF(K))*CONV
20     RK=1.0
       TVS(NPK)=0.0
       TVSFP=TVSFP+TVS(K-1)
       CALL VOLCUT(DDFDF(K),A,FA,CABHT,CABRAD,H,X,W,WK,IFLAG,
      1  VOL(K))
       VOL(K)=VOL(K)*SF
       VOL(K)=VOL(K)-TVSFP
C
C      CHECK IF DRAGLINE IS IN SHALLOW OR MEDIUM OVERBURDEN
C
C
C      CALCULATE THE REQUIRED HORIZONTAL DISTANCE
C      TO INITIAL DUMPING POINT FROM THE DIGGING FACE
30     DO 50 J=1,N
C
C      CALCULATE SWING ANGLE TO EACH X-SECTION FROM A GIVEN POSTION
C
       DTXS(K,J)=DTXS(K,J-1)-UIL
       SA=ACOS(DTXS(K,J)/DR)*CONV-SAA
C
C      CALCULATE VOLUME SPOILED INTO EACH X-SECTION
C
       UVT(J)=UV(K-1,J)+UVT(J)
       CONST1=W*TAND(B)*UIL
       CONST2=H/TAND(A)+W/4.0
       CONST3=SQRT(DR*DR-DTXS(K,J)*DTXS(K,J))-DDFH(K)
       UV(K,J)=CONST1*(CONST3-CONST2)-UVT(J)
```

```
C
C     CHECK IF VOLUME REMOVABLE MINUS TOTAL VOLUME SPOILED
C     FROM A GIVEN POSITION IS ENOUGH TO FILL THE GIVEN
C     X-SECTIONAL VOLUME
C
      IF(UV(K,J).LE.(VOL(K)-TVS(K))) GO TO 40
      UV(K,J)=VOL(K)-TVS(K)
C
C     WEIGHTED SWING ANGLE
C
40    WSA(K)=WSA(K)+SA*UV(K,J)
C
C     FIND TOTAL VOLUME SPOILED FROM A POSITION BY SUMMING
C     HOW MUCH VOLUME IN EACH X-SECTIONAL VOLUME
C
      TVS(K)=TVS(K)+UV(K,J)
C
C     CHECK WHETHER VOLUME REMOVEABLE FROM A POSITION DEPLETED
C
      IF(TVS(K).EQ.VOL(K)) GO TO 60
C
C     IF YES MOVE TO NEXT POSITION, IF NOT KEEP SPOILING
C
50    CONTINUE
C
C     CALCULATE AVERAGE SWING ANGLE NECESSARY FOR A GIVEN POSITION
C
60    IF(TVS(K).EQ.0.0)GO TO 64
      ASA(K)=WSA(K)/TVS(K)
      IF(K.EQ.1)ASA(1)=WSA(1)/(TVS(1)+CDVOL)
      GO TO 65
64    ASA(K)=0.0
C     CALCULATE THE DISTANCE DRAGLINE WALKS TO A GIVEN POSITION
C
65    WD(K)=SQRT((DDFDF(K)-DDFDF(K-1))**2+(DDFH(K)-DDFH(K-1))*
     1  *2)
C
C     CALL SUBROUTINE TO FIND AVERAGE CYCLE TIME
C
      CALL CYCLE(ST1,ST2,SCC,ASA(K),RK,TVS(K),BC,WD(K)
     1  ,WS,CLT,M,CDVOL,TT(K),TCT(K),WT(K),DT,BPT)
C
C     FIND TOTAL TIME SPENT FOR THE SEGMENT
C
      TTSS=TTSS+TT(K)
C
C     FIND TOTAL VOLUME SPOILED FOR THE SEGMENT
C
      TVSS=TVSS+TVS(K)
      TWSA=TWSA+WSA(K)
C
```

```
C     FIND TOTAL CVYCLE TIME AND WALKING TIME FOR THE SEGMENT
C
      TOTCT=TOTCT+TCT(K)
      TOTWT=TOTWT+WT(K)
70    CONTINUE
      TVSFK=0.0
      TVSFP=0.0
      IF((IFLAG.EQ.1).AND.(M.EQ.JI))GO TO 177
      TVS(1)=TVS(1)+CDVOL
      TNOC=TVSS/BC
C
C     FIND FINAL AVERAGE CYCLE TIME,AND DRAGLINE PRODUCTION
C
      FACT=TTSS/TNOC
      NOCPH=3600.0/FACT
C     FIND FINAL AVERAGE SWING TIME
      DPPH=NOCPH*BC
      DPPH=DPPH/27.0
      DPPHB=DPPH/SF
      BC=BC/(27.0*FF)
      FASA=TWSA/TVSS
C
C     CALCULATE COST OF PRODUCTION
C
      PCOSTH=PCH*PCKH
      MCH=0.06*DPPHB
      LCH=3.0*LR
      TOCH=PCOSTH+MCH+LCH
      DCY=DIC/DOL
      IF(CRF.NE.0.0)DCY=DIC*CRF
      DCH=DCY/SH
      AVI=DIC*(DOL+1.0)/(2.0*DOL)
      ITI=ITIP*AVI
      ITIH=ITI/SH
      TOWCH=DCH+ITIH
      TCH=TOCH+TOWCH
      ET=SH*(AV)*(JF)
      DAP=ET*DPPH
      DAPB=DAP/SF
      AD=(DAPB*27.0)/DEPTH
      CV=AD*CT
      CTON=((CV*CD)/2000.0)*RF
      CTHR=CTON/SH
      TOCTON=TOCH/CTHR
      TOWCTN=TOWCH/CTHR
      TCTON=TOCTON+TOWCTN
      TOCYD=TOCH/DPPH
      TOWYD=TOWCH/DPPH
      TCYD=TOCYD+TOWYD
      H=H+CDBH
      PRCCD=(CDVOL/TVSS)*100
```

```
      TVS(MI)=TVSLKP
      TVS(NPK)=VSFFKP
      SF=SF*100.
      RF=RF*100.
      AV=AV*100.
      JF=JF*100.
      DO 195 K=1,NTP
      TVS(K)=TVS(K)/27.0
      TCT(K)=TCT(K)/3600.0
      WT(K)=WT(K)/3600.0
      TT(K)=TT(K)/3600.0
195   CONTINUE
      WRITE(KY,200)H,CT,A,B,C,SF,RF,W,X,CDBH,EW,MT,DR,BC,SH,AV,
     1  JF
200   FORMAT(1X,28X,'PROPERTY CHARACTERISTICS',//,1X,18X,
     1  'OVERBURDEN HEIGHT',9X,':',F10.1,2X,'FT',/1X,18X,
     2  'COAL THICKNESS',12X,':',F10.1,2X,'FT',/,1X,18X,
     3  'HIGHWALL ANGLE',12X,':',F10.1,2X,'DEGREES',
     4  /,1X,18X,'SPOIL ANGLE OF REPOSE',5X,':',F10.2,
     5  2X,'DEGREES',/,1X,18X,'COAL HIGHWALL ANGLE',7X,':',
     6  F10.2,2X,'DEGREES',/,1X,18X,'SWELL FACTOR',14X,':',
     7  F10.2,2X,'%',/,1X,18X,'COAL RECOVERY',13X,':',
     8  F10.2,2X,'%',/19X'PIT WIDTH',17X,':',F10.2,2X,'FT',
     8  /19X,'CUT LENGTH',16X,':',F10.2,2X,'FT',
     8  /1X,18X,'CHOP DOWN BENCH HEIGHT',4X,':',F10.2,2X,'FT',
     8  /1X,18X,'PIT EXTENTION',13X,':',F10.2,2X,'FT'
     8  //,1X,27X,'DRAGLINE CHARACTERISTICS',
     9  //,1X,18X,'DRAGLINE TYPE',13X,':',5X,A10,/,1X,18X,
     1  'DRAGLINE REACH',12X,':',F10.2,2X,'FT',/,1X,18X,
     2  'BUCKET CAPACITY',11X,':',F10.2,2X,'CUBIC YARD',/,1X,
     3  18X,'SCHEDULED HOURS',11X,':',F10.2,2X,'HOURS/YEAR',/1X,
     4  18X,'MECHANICAL AVAILABILITY',3X,':',F10.2,2X,'%',/,1X,18X,
     5  'JOB FACTOR',16X,':',F10.2,2X,'%',//)
      WRITE(KY,450)FASA,FACT,DPPH,DAP,DPPHB,DAPB,CDVOL,RHVOL,
     1  PRCRH,PRCCD,CTON,TOCTON,TOCYD,TOWCTN,TOWYD,TCTON,TCYD
450   FORMAT(1X,28X,'DRAGLINE PRODUCTION AND COST',/,1X,39X,
     1  'SUMMARY',//,1X,18X,'AVERAGE SWING ANGLE',8X,':',F10.2,
     2  2X,'DEGREES',/,1X,18X,'AVERAGE CYCLE TIME',9X,':',
     3  F10.2,2X,'SECONDS',//,1X,18X,'PRODUCTION RATE (LOOSE)',4X,':'
     3  F10.2,2X,'CU. YD/HR',/,1X,18X,'TOTAL VOLUME SPOILED (LS)',2X,
     4  ':',F10.1,2X,'CU.YD/YEAR',//,1X,18X,'PRODUCTION RATE',
     4  ' (BANK) ',4X,':',F10.2,2X,'CU. YD/HR',/,1X,18X,
     4  'TOTAL VOLUME SPOILED (BANK)',':',F10.1,2X,'CU. YD/YR'
     4  ,//,19X,'TOTAL VOLUME CHOPPED'
     1  ,7X,':',F10.2,2X,'CU.YD/YEAR'/1X,18X,
     5  'TOTAL VOLUME REHANDLED',5X,':',F10.2,2X,'CU.YD/YEAR',
     6  /,1X,18X,'PERCENT REHANDLED',10X,':',F10.2,2X,'%',
     6  /,1X,18X,'PERCENT CHOP DOWN',10X,':',F10.2,2X,'%',//,
     7  19X,'TOTAL COAL MINED',11X,':',F10.2,2X,'TONS',//,19X,
     8  'OPERATING COST',13X,':',F10.2,2X,'$/TON',/
     8  1X,45X,':',F10.2,2X,'$/CU. YARD',//,1X,18X,
```

```
     1  'OWNERSHIP COST',13X,':',F10.2,2X,
     2  '$/TON',/,1X,45X,':',F10.2,2X,'$/CU. YARD',
     3  //,1X,18X,'TOTAL COST',17X,':',F10.2,2X,
     4  '$/TON',/,1X,45X,':',F10.2,2X,'$/CU.YARD'//)
      WRITE(KY,198)
198   FORMAT(1X,28X,'DRAGLINE PRODUCTION SUMMARY',/,1X,
     1  40X,'FOR',/1X,35X,'EACH POSITION',//)
      IJ=1
      IL=2
      DO 445 J=1,NTP
      WRITE(KY,290)
290   FORMAT(19X,'----------------------------------',
     1  '-----------------')
      WRITE(KY,300)(K,K=IJ,IL)
300   FORMAT(1X,18X,'POSITION',24X,15(I2,13X))
      WRITE(KY,290)
350   FORMAT(1X,18X,15A5)
      WRITE(KY,400)(TVS(K),K=IJ,IL)
400   FORMAT(1X,18X,'VOLUME SPOILED (CU. YD)',3X,2(F10.2,4X))
      WRITE(KY,410)(ASA(K),K=IJ,IL)
410   FORMAT(1X,18X,'AVERAGE SWING ANGLE (D)',3X,2(F10.2,4X))
      WRITE(KY,420)(TCT(K),K=IJ,IL)
420   FORMAT(1X,18X,'EXCAVATING TIME (HRS)',5X,2(F10.2,4X))
      WRITE(KY,430)(WT(K),K=IJ,IL)
430   FORMAT(1X,18X,'WALKING TIME (HRS)',8X,2(F10.2,4X))
      WRITE(KY,440)(TT(K),K=IJ,IL)
440   FORMAT(1X,18X,'TOTAL TIME (HRS)',10X,2(F10.2,4X))
      IF(IL.EQ.NTP)STOP
      IJ=IL+1
      IL=IL+2
      IF(IL.GT.NTP)IL=NTP
445   CONTINUE
      END
```

```
      SUBROUTINE CYCLE(ST1,ST2,SCC,ASA,RK,TVS,BC,WD,WS,CLT,
     1  M,CDVOL,TT,TCT,WT,DT,BPT)
      SM=(ST2-ST1)/30.
      AST=(ASA*SM+SCC)
      ACT=(AST+DT+BPT)*RK
      NOC=(TVS/BC)
      IF(M.EQ.1)NOC=(TVS+CDVOL)/BC
      TCT=FLOAT(NOC)*ACT
      WT=WD/WS+CLT
      IF(TVS.EQ.0.0)WT=0.0
      TT=TCT+WT
      RETURN
      END
```

```
      SUBROUTINE VOLKEY(DLDIST,A,FA,CABHT,CABRAD,H,CUT,BOTKEY
     1   ,IFLAG,VOL)
      DEPTH=H
      IF(IFLAG.EQ.1)DEPTH=DEPTH/2.
      THTAN=TAND(FA)
      DIGTAN=CABHT/(DLDIST-CABRAD)
      OF=DLDIST+CUT+DEPTH/THTAN
      OJ=DEPTH/TAND(FA)
      XBROW=OJ
      XINT=OF-CABRAD-((DEPTH+CABHT)/DIGTAN)
      IF(XINT.GT.CUT)XINT=CUT
      UHT=CUT*DIGTAN
      LHT=DEPTH-UHT
      TOPKEY=(DEPTH/TAND(A))*2.0+BOTKEY
      MIDKEY=BOTKEY+(LHT/DEPTH)*(TOPKEY-BOTKEY)
      C=-XINT*DIGTAN
      BXLONG=DEPTH/THTAN-C/(THTAN-DIGTAN)
      IF(XINT.LE.0.0) GO TO 10
      IF(XINT.LE.OJ)GO TO 11
      IF(XINT.GE.OJ)GO TO 12
10    VOL=(BXLONG+CUT)*UHT*(TOPKEY+MIDKEY)/4.0
      GO TO 13
11    VOL=CUT*UHT*(TOPKEY+MIDKEY)/4.+((DEPTH**2)
     1   *(TOPKEY+BOTKEY))/(4.0*THTAN)-(XBROW-XINT)
     1   *LHT*((BOTKEY+MIDKEY)/4.0)
      GO TO 13
12    AREA=DEPTH*(TOPKEY+BOTKEY)/2.0
      XBROW=OJ
      VOL=(XBROW+CUT-XINT)*AREA/2.0+(XINT-XBROW)*AREA+
     1   XBROW*AREA/2.0
13    RETURN
      END
```

```
      SUBROUTINE VOLCUT(DLDIST,A,FA,CABHT,CABRAD,H,CUT,W,
     1  BOTKEY,IFLAG,VOL)
      DEPTH=H
      IF(IFLAG.EQ.1)DEPTH=DEPTH/2.
      THTAN=TAND(FA)
      DIGTAN=CABHT/(DLDIST-CABRAD)
      OF=DLDIST+CUT+DEPTH/THTAN
      OJ=DEPTH/TAND(FA)
      XINT=OF-CABRAD-((DEPTH+CABHT)/DIGTAN)
      IF(XINT.GT.CUT)XINT=CUT
      XBROW=OJ
      UHT=CUT*DIGTAN
      LHT=DEPTH-UHT
      TOPKEY=(DEPTH/TAND(A))*2.0+BOTKEY
      MIDKEY=BOTKEY+(LHT/DEPTH)*(TOPKEY-BOTKEY)
      WIDTH=W-TOPKEY
      C=-XINT*DIGTAN
      BXLONG=DEPTH/THTAN-C/(THTAN-DIGTAN)
      IF(XINT.LE.0)GO TO 10
      IF(XINT.LE.OJ) GO TO 11
      IF(XINT.GT.OJ)GO TO 12
10    Z1ARE1=UHT*CUT/2.
      Z1ARE2=UHT*BXLONG/2.
      Z1TVOL=(Z1ARE1+Z1ARE2)*WIDTH
      XSIDE=UHT**2.*(TOPKEY-BOTKEY-DEPTH/TAND(A))/(2.*DEPTH)
      Z2TVOL=XSIDE*(CUT+BXLONG)/2.0
      VOL=Z1TVOL+2.*Z2TVOL
      RETURN
11    Z1ARE1=UHT*CUT/2.
      Z1AR23=DEPTH*OJ/2.
      Z1ARE3=(DEPTH-UHT)*(XBROW-XINT)/2.0
      Z1VOL=(Z1ARE1+Z1AR23-Z1ARE3)*WIDTH
      XSIDE=UHT**2/(2.*TAND(A))
      Z2VOL1=XSIDE*CUT/2.0
      TXSIDE=DEPTH**2./(2.*TAND(A))
      Z2VOL2=TXSIDE*XBROW/2.
      Z2VOL3=(TXSIDE-XSIDE)*(XBROW-XINT)/2.
      Z2TVOL=Z2VOL1+Z2VOL2-Z2VOL3
      VOL=Z1VOL+2.*Z2TVOL
      RETURN
12    Z1ARE1=DEPTH*(XBROW+CUT-XINT)/2.
      Z1ARE2=DEPTH*(XINT-XBROW)
      Z1ARE3=DEPTH*(XBROW)/2.0
      Z1TVOL=(Z1ARE1+Z1ARE2+Z1ARE3)*WIDTH
      XSIDE=DEPTH**2./(2.*TAND(A))
      Z2VOL1=XSIDE*(XBROW+CUT-XINT)/2.
      Z2VOL2=XSIDE*(XINT-XBROW)
      Z2VOL3=XSIDE*XBROW/2.
      Z2TVOL=Z2VOL1+Z2VOL2+Z2VOL3
      VOL=Z1TVOL+2.*Z2TVOL
      RETURN
```

END

```
C      THIS IS THE COMPUTER PROGRAM TO CALCULATE PRODUCTION OF A DRAGLINE
C      TO SIMULATE ITS CHOPDOWN EXTENDED BENCH OPERATION.
C      PROGRAMED BY KADRI DAGDELEN
C      PROGRAM NAME : EXT.FOR
C
C
C      INITIALIZE VARIABLES
C
       DIMENSION DDFDF(0/15),DDFH(0/15),DTXS(15,0/30),TVS(0/15)
      1  ,UV(0/15,0/30),VOL(0/15),ASA(15),TT(15),TCT(15),WD(15),
      1  WT(15),UVT(30),WSA(15),TVSB(15)
       REAL ITIP,LR,LCH,MCH,JF
       DOUBLE PRECISION MT
       DATA TTSFP,TTSFK/2*0.0/,TVSS,TTSS/2*0.0/,TVS/16*0.0/,
      1  UV/496*0.0/,VOL(0)/0.0/,CONV/57.2957/,TVSFK,TVSFP,TCTFB/
      1  3*0.0/,UVT/30*0.0/,WSA/15*0.0/,TWSA,TOTCT,TOTWT/3*0.0/,
      1  TVSB/15*0.0/,TT/15*0.0/,CDVOL/0.0/,TCTCD/0.0/,CDASA/0.0/
       OPEN(UNIT=8,FILE='EXT',ACCESS='SEQIN')
C      WRITE(4,98)
C98    FORMAT(10X,'DO YOU WANT THE OUTPUT ON THE LINE PRINTER?',
C      1 /10X,'TYPE   YES  OR  NO')
C      READ(4,99)ANS
C99    FORMAT(A5)
C      IF(ANS.EQ.YES)KY=6
C      IF(ANS.EQ.NO)KY=4
       KY=6
       READ(8,100)H,W,CT,CD,A,B,C,FA,SF,X,WK
100    FORMAT(12F)
       READ(8,105)CDBH
105    FORMAT(F)
       READ(8,110)MT
110    FORMAT(A10)
       READ(8,120)DR,BC,CABHT,CABRAD,P
120    FORMAT(5F)
       READ(8,150)DT,BPT,ST1,ST2,SCC,WS,CLT
150    FORMAT(7F)
       READ(8,160)SH,AV,JF,RF,FF
160    FORMAT(5F)
       READ(8,170)DIC,PCKH,PCH,LR,DOL,CRF,ITIP
170    FORMAT(7F)
       READ(8,130)NPK,NTP,N
130    FORMAT(3I)
       READ(8,140)(DDFDF(J),DDFH(J),J=1,NTP)
140    FORMAT(2F)
       READ(8,171)IFLAG
171    FORMAT(I)
       IF(IFLAG.EQ.0)GO TO 174
       READ(8,172)NFSIKP,NFSLKP,NFSTP
172    FORMAT(3I)
       READ(8,173)(DDFDF(J),DDFH(J),J=NFSIKP,NFSTP)
```

```
173    FORMAT(2F)
       IF(IFLAG.EQ.1)GO TO 176
174    TOPKEY=(H/TAND(A))*2.+WK
       IF(TOPKEY.LE.W-5.)GO TO 176
       WRITE(4,175)
175    FORMAT(1X,10X,'OVERBURDEN IS TOO DEEP',/
      1  1X,10X,'IT WILL BE MINED IN TWO LIFTS',/
      1  1X,10X,'ENTER NEW SET OF DRAGLINE',/
      1  1X,10X,'POSITIONS FOR SECOND LIFT')
       STOP
C   INITIALIZE VARIABLES
176    SF=1.0+SF/100.
       IF(IFLAG.EQ.0)NFSTP=NTP
       PDR=DR
       FA=A
       BC=BC*FF*27.0
       UIL=X/FLOAT(N)
       DO 15 I=1,NFSTP
       DTXS(I,0)=DDFDF(I)-P+X+UIL/2.
15     CONTINUE
       DEPTH=H
       SWELL=SF
       IF(CDBH.EQ.0.)GO TO 301
       HE=CDBH/TAND(A)
       DO 16 J=1,NFSTP
       DDFH(J)=DDFH(J)
16     CONTINUE
C  CALCULATE AVERAGE SWING ANGLE FOR CHOP DOWN
       YD=(3./2.)*X-DDFDF(1)
       XD=W-DDFH(K)
       CDASA=((ATAN(XD/YD))+(ASIN(DDFH(K)/DR)))*CONV
       CDVOL=(CDBH*X*W)*SF
       TVSS=CDVOL
C
C CALCULATE AVERAGE CYCLE TIME FOR CHOP DOWN
       SM=(ST2-ST1)/30.0
       AST=(CDASA*SM+SCC)
       ACT=(AST+DT+BPT)*1.5
C
C  CALCULATE TOTAL TIME SPENT FOR CHOPING DOWN
       NOC=CDVOL/(BC*0.8)
       TCTCD=FLOAT(NOC)*ACT
C
C  SPOIL ROOM GAINED FROM CHOPPING
       SRG=W*CDBH*TAND(B)/TAND(A)
C
C  EFFECTIVE HEIGHT REDUCTION FROM CHOPPING
       HG=SRG/(W*SF)
       H=H-HG
C
C REQUIRED DRAGLINE OPERATING RADIUS
```

```
301    ODR=H/TAND(A)+CT/TAND(C)+H*SF/TAND(B)+W/4.0+P
       DOR=ODR+X**2/(4.0*ODR)
       IF(DR.GT.DOR)WRITE(4,302)
302    FORMAT(10X,'DRAGLINE HAS ENOUGH REACH',
      1  /10X,'RUN "SIDE CASTING MODEL"')
       IF (DR.GT.DOR)STOP
       H=DEPTH-CDBH
C
C   REQUIRED PIT WIDTH EXTENSION
       EW=DOR-DR
       IF (EW.LE.0.0)EW=0.0
       DDFH(0)=DDFH(NTP)-EW
       DDFDF(0)=-X+DDFDF(NTP)
C
C  VOLUME OF THE MATERIAL REQUIRED TO EXTEND THE BENCH
       CALL EXVOL(H,CT,EW,X,W,A,B,C,EV)
C ALL THE CHOP DOWN MATERIAL USED;CALCULATE VOLUME NEEDED FROM THE KEY C
303    EVB=EV
       IF(CDVOL.GE.EV)CDVOL=EV
       CDBH=CDVOL/(W*X*SF)
       EV=EV-CDVOL
C
C   CALCULATE THE VOLUMES ALREADY SPOILED FROM THE
C    EXTENDED BENCH INTO THE CROSS SECTIONAL INTERVALS
       CALL VOLS(H,CT,EW,W,A,B,C,UIL,VOLAS)
       VOLASC=(VOLAS/UIL)*X
       DO 12 J=1,N
       UVT(J)=VOLAS
12     CONTINUE
       RHVOL=EVB-VOLASC
       TOPKEY=(H/TAND(A))*2.+WK
       IF(IFLAG.EQ.1)TOPKEY=(H/TAND(A))+WK
       JM=1
       M=0
       MI=NPK
       JI=NTP
177    IF((IFLAG.EQ.1).AND.(M.EQ.JI))JM=NFSIKP
       IF((IFLAG.EQ.1).AND.(M.EQ.JI))NTP=NFSTP
       IF((IFLAG.EQ.1).AND.(M.EQ.JI))NPK=NFSLKP
       TVSL=TVS(JI)
C
C FINISH THE BENCH EXTENTION AND SPOIL THE REST BY SIDE CASTING
       DO 70 K=JM,NTP
C
C      CHECK WHETHER DRAGLINE IS IN KEY CUT
C
       IF(K.GT.NPK) GO TO 20
C
C
C   DRAGLINE IS IN KEY CUT POSTION; CALCULATE VOLUME REMOVEABLE
C
```

```
      COK=DDFH(K)-(W-TOPKEY/2.)
      SAA=ATAN(COK/DDFDF(K))*CONV
      RK=1.5
      TVS(JI)=0.0
      TVS(NTP)=0.0
      TVSFK=TVSFK+TVS(K-1)
      CALL  VOLKEY(DDFDF(K),A,FA,CABHT,CABRAD,H,X,WK,IFLAG,VOL(K))
      VOL(K)=VOL(K)*SF
      VOL(K)=VOL(K)-TVSFK
      VSFLKP=VOL(MI)
      VSFFKP=VOL(NPK)
      GO TO 30
C
C     IN PRIME CUT POSITION; CALCULATE VOLUME REMOVABLE
C
      COM=DDFH(K)-(W-TOPKEY)/2.
      SAA=ATAN(COM/DDFDF(K))*CONV
      IF(K.NE.NTP)GO TO 20
      IF(EW/2..GT.DDFH(NTP))GO TO 18
      COEB=DDFH(NTP)+EW/2.
      SAA=(ATAN(COEB/DDFDF(NTP))*CONV)
18    COEB=(EW/2.0-DDFH(NTP))
      SAA=-(ATAN(COEB/DDFDF(NTP))*CONV)
20    RK=1.0
      I=K
      TVS(NPK)=0.0
      TVSFP=TVSFP+TVS(K-1)
      CALL  VOLCUT(DDFDF(K),I,JI,A,B,FA,CABHT,CABRAD,H,CT,X,SF,W,
     1  EW,WK,IFLAG,RHVOL,NTP,VOL(K))
      VOL(K)=VOL(K)
      VOL(K)=VOL(K)-TVSFP
C
C  CHECK IF ANY MORE MATERIAL NEEDED TO EXTEND THE BENCH
30    IF(EV.LE.0.0)GO TO 304
C  IF YES  EXCAVATE FROM FROM THE KEYCUT TO EXTEND THE BENCH
      EV=EV-VOL(K)
      IF(EV.LE.0.0) GO TO 305
C AVERAGE SWING ANGLE TO EXTEND THE BENCH
      ASA(K)=90.0+(ACOS(DDFH(K)/DR))*CONV-SAA
      TVS(K)=VOL(K)
      GO TO 65
305   TVSB(K)=VOL(K)+EV
      SA=90.0+(ACOS(DDFH(K)/DR))*CONV-SAA
      WSA(K)=SA*TVSB(K)
      VOL(K)=VOL(K)-TVSB(K)
C     CALCULATE VOLUME SPOILED FROM EACH POSITION INTO EACH X-SECTION
C
C
304   IF(K.EQ.NTP)DR=DR+EW
      DO 50 J=1,N
      DTXS(K,J)=DTXS(K,J-1)-UIL
```

```
      UVT(J)=UVT(J)+UV(K-1,J)
      SA=ACOS(DTXS(K,J)/DR)*CONV-SAA
      CONST1=W*TAND(B)*UIL
      CONST2=H/TAND(A)+W/4.0
      CONST3=SQRT(DR*DR-DTXS(K,J)*DTXS(K,J))-DDFH(K)
      UV(K,J)=CONST1*(CONST3-CONST2)-UVT(J)
      IF(UV(K,J).LT.0.0)UV(K,J)=0.0
      IF(UV(K,J).LE.(VOL(K)-TVS(K))) GO TO 40
      UV(K,J)=VOL(K)-TVS(K)
40    WSA(K)=WSA(K)+SA*UV(K,J)
      TVS(K)=TVS(K)+UV(K,J)
      IF(TVS(K).EQ.VOL(K)) GO TO 60
50    CONTINUE
60    TVS(K)=TVSB(K)+TVS(K)
      IF(TVS(K).NE.0.0)ASA(K)=WSA(K)/TVS(K)
65    WD(K)=SQRT((DDFDF(K)-DDFDF(K-1))**2+(DDFH(K)-DDFH(K-1))*
     1  *2)
      IF(K.EQ.NTP)WD(K)=WD(K)+EW
C
C     CALL SUBROUTINE TO FIND AVERAGE CYCLE TIME
C
      IF(K.EQ.1)WSA(1)=ASA(1)*TVS(1)+CDVOL*CDASA
      ASA(1)=WSA(1)/(TVS(1)+CDVOL)
      CALL CYCLE(ST1,ST2,SCC,ASA(K),RK,TVS(K),BC,WD(K),WS,
     1  CLT,DT,BPT,TT(K),TCT(K),WT(K))
      IF(K.EQ.1)TT(1)=TT(1)+TCTCD
      TTSS=TTSS+TT(K)
      TVSS=TVSS+TVS(K)
      WSA(K)=ASA(K)*TVS(K)
      IF(K.EQ.1)WSA(1)=ASA(1)*(TVS(1)+CDVOL)
      TWSA=TWSA+WSA(K)
      TOTCT=TOTCT+TCT(K)
      TOTWT=TOTWT+WT(K)
      M=K
70    CONTINUE
      TVSFK=0.0
      TVSFP=0.0
      DR=PDR
      IF(IFLAG.EQ.1)SF=SWELL
      IF((IFLAG.EQ.1).AND.(M.EQ.JI))GO TO 177
      TNOC=TVSS/BC
      FACT=TTSS/TNOC
      NOCPH=3600.0/FACT
      DPPH=NOCPH*BC/27.
      DPPHB=DPPH/SF
      BC=BC/(27.*FF)
      FASA=TWSA/TVSS
      BV=(W*DEPTH*X)*SWELL
      PRCRH=(RHVOL/BV)*100.
      PRCCD=(CDVOL/BV)*100.0
C
```

```
C      CALCULATE COST OF PRODUCTION
C
       PCOSTH=PCH*PCKH
       MCH=0.06*DPPHB
       LCH=3.0*LR
       TOCH=PCOSTH+MCH+LCH
       DCY=DIC/DOL
       IF(CRF.NE.0.0)DCY=DIC*CRF
       DCH=DCY/SH
       AVI=DIC*(DOL+1.0)/(2.0*DOL)
       ITI=ITIP*AVI
       ITIH=ITI/SH
       TOWCH=DCH+ITIH
       TCH=TOCH+TOWCH
       ET=SH*(AV)*(JF)
       DAP=ET*DPPH
       DAPB=DAP/SF-((DAP/SF)*PRCRH/100.)
       AD=DAPB*27./DEPTH
       CV=AD*CT
       CTON=((CV*CD)/2000.0)*RF
       CTHR=CTON/SH
       TOCTON=TOCH/CTHR
       TOWCTN=TOWCH/CTHR
       TCTON=TOCTON+TOWCTN
       TOCYD=TOCH/DPPH
       TOWYD=TOWCH/DPPH
       TCYD=TOCYD+TOWYD
       RHVOL=DAP*PRCRH/100.
       TVS(1)=TVS(1)+CDVOL
       CDVOL=DAP*PRCCD/100.
       TVS(MI)=VSFLKP
       TVS(NPK)=VSFFKP
       TVS(JI)=TVSL
       H=DEPTH
       SF=SWELL*100.
       RF=RF*100.
       AV=AV*100.
       JF=JF*100.
       DO 195 K=1,NTP
       TVS(K)=TVS(K)/27.0
       TCT(K)=TCT(K)/3600.0
       WT(K)=WT(K)/3600.0
       TT(K)=TT(K)/3600.0
195    CONTINUE
       WRITE(KY,200)H,CT,A,B,C,SF,RF,W,X,CDBH,EW,MT,DR,BC,SH,AV,
     1  JF
200    FORMAT(1X,28X,'PROPERTY CHARECTERISTICS',//,1X,18X,
     1  'OVERBURDEN HEIGHT',9X,':',F10.1,2X,'FT',/1X,18X,
     2  'COAL THICKNESS',12X,':',F10.1,2X,'FT',/,1X,18X,
     3  'HIGHWALL ANGLE',12X,':',F10.1,2X,'DEGREES',
     4  /,1X,18X,'SPOIL ANGLE OF REPOSE',5X,':',F10.2,
```

```
     5  2X,'DEGREES',/,1X,18X,'COAL HIGHWALL ANGLE',7X,':',
     6  F10.2,2X,'DEGREES',/,1X,18X,'SWELL FACTOR',14X,':',
     7  F10.2,2X,'%',/,1X,18X,'COAL RECOVERY',13X,':',
     8  F10.2,2X,'%',/19X'PIT WIDTH',17X,':',F10.2,2X,'FT',
     8  /19X,'CUT LENGTH',16X,':',F10.2,2X,'FT',
     8  /1X,18X,'CHOP DOWN BENCH HEIGHT',4X,':',F10.2,2X,'FT',
     8  /1X,18X,'PIT EXTENTION',13X,':',F10.2,2X,'FT'
     8  //,1X,27X,'DRAGLINE CHARECTERISTICS',
     9  //,1X,18X,'DRAGLINE TYPE',13X,':',5X,A10,/,1X,18X,
     1  'DRAGLINE REACH',12X,':',F10.2,2X,'FT',/,1X,18X,
     2  'BUCKET CAPACITY',11X,':',F10.2,2X,'CUBIC YARD',/,1X,
     3  18X,'SCHEDULED HOURS',11X,':',F10.2,2X,'HOURS/YEAR',/1X,
     4  18X,'MECHANICAL AVAILABILITY',3X,':',F10.2,2X,'%',/,1X,18X,
     5  'JOB FACTOR',16X,':',F10.2,2X,'%',//)
        WRITE(KY,450)FASA,FACT,DPPH,DAP,DPPHB,DAPB,CDVOL,RHVOL,
     1  PRCRH,PRCCD,CTON,TOCTON,TOCYD,TOWCTN,TOWYD,TCTON,TCYD
450     FORMAT(1X,28X,'DRAGLINE PRODUCTION AND COST',/,1X,39X,
     1  'SUMMARY',//,1X,18X,'AVERAGE SWING ANGLE',8X,':',F10.2,
     2  2X,'DEGREES',/,1X,18X,'AVERAGE CYCLE TIME',9X,':',
     3  F10.2,2X,'SECONDS',//,1X,18X,'PRODUCTION RATE (LOOSE)',4X,':'
     3  F10.2,2X,'CU. YD/HR',/,1X,18X,'TOTAL VOLUME SPOILED (LS)',2X,
     4  ':',F10.1,2X,'CU.YD/YEAR',//,
     4  1X,18X,'PRODUCTION RATE (BANK) ',5X,':',F10.2,2X,'CU.YD/HR',
     4  /,1X,18X,'TOTAL VOLUME SPOILED (BANK)',':',F10.1,2X,
     4  'CU. YD/YEAR',//,19X,'TOTAL VOLUME CHOPPED'
     1  ,7X,':',F10.2,2X,'CU.YD/YEAR'/1X,18X,
     5  'TOTAL VOLUME REHANDLED',5X,':',F10.1,2X,'CU.YD/YEAR',
     6  /,1X,18X,'PERCENT REHANDLED',10X,':',F10.2,2X,'%',
     6  /,1X,18X,'PERCENT CHOP DOWN',10X,':',F10.2,2X,'%',//,
     7  19X,'TOTAL COAL MINED',11X,':',F10.2,2X,'TONS',//,19X,
     8  'OPERATING COST',13X,':',F10.2,2X,'$/TON',/
     8  1X,45X,':',F10.2,2X,'$/CU. YARD',//,1X,18X,
     1  'OWNERSHIP COST',13X,':',F10.2,2X,
     2  '$/TON',/,1X,45X,':',F10.2,2X,'$/CU. YARD',
     3  //,1X,18X,'TOTAL COST',17X,':',F10.2,2X,
     4  '$/TON',/,1X,45X,':',F10.2,2X,'$/CU.YARD'//)
        WRITE(KY,198)
198     FORMAT(1X,28X,'DRAGLINE PRODUCTION SUMMARY',/,1X,
     1  40X,'FOR',/1X,35X,'EACH POSITION',//)
        IJ=1
        IL=2
        DO 445 J=1,NTP
        WRITE(KY,290)
290     FORMAT(19X,'-----------------------------------',
     1  '------------------')
        WRITE(KY,300)(K,K=IJ,IL)
300     FORMAT(1X,18X,'POSITION',24X,15(I2,13X))
        WRITE(KY,290)
350     FORMAT(1X,18X,15A5)
        WRITE(KY,400)(TVS(K),K=IJ,IL)
400     FORMAT(1X,18X,'VOLUME SPOILED (CU. YD)',3X,2(F10.2,4X))
```

```
      WRITE(KY,410)(ASA(K),K=IJ,IL)
410   FORMAT(1X,18X,'AVERAGE SWING ANGLE (D)',3X,2(F10.2,4X))
      WRITE(KY,420)(TCT(K),K=IJ,IL)
420   FORMAT(1X,18X,'EXCAVATING TIME (HRS)',5X,2(F10.2,4X))
      WRITE(KY,430)(WT(K),K=IJ,IL)
430   FORMAT(1X,18X,'WALKING TIME (HRS)',8X,2(F10.2,4X))
      WRITE(KY,440)(TT(K),K=IJ,IL)
440   FORMAT(1X,18X,'TOTAL TIME (HRS)',10X,2(F10.2,4X))
      IF(IL.EQ.NTP)STOP
      IJ=IL+1
      IL=IL+2
      IF(IL.GT.NTP)IL=NTP
445   CONTINUE
      END
```

```
SUBROUTINE EXVOL(AE,ED,AG,X,W,A,B,C,EV)
OP=W
AD=AE+ED
EF=AE/TAND(A)
BC=AD
GB=BC/TAND(B)
AB=AG+GB
FH=ED
HO=FH/TAND(C)
DP=EF+HO+OP
PC=AB-DP
IF(PC.LE.0.0)PC=0.0
EA1=AB*AD
EA2=GB*BC/2.0
EA3=AE*EF/2.
EA4=EF*ED+FH*HO/2.0
EA5=PC**2.*TAND(B)/4.
EA=EA1-(EA2+EA3+EA4+EA5)
EV=EA*X
RETURN
END
```

```
      SUBROUTINE VOLS(AE,ED,AG,W,A,B,C,UIL,VOLAS)
      TU=AE+ED
      AD=TU
      AY=AE/TAND(A)+ED/TAND(C)
      YQ=AD/TAND(B)
      AQ=AY+YQ
      TQ=(AQ-AG)/2.
      TS=TQ*TAND(B)
      SU=TU-TS
      AROSC=SU**2./TAND(B)
C     CONSIDER THE SECOND CASE
      GB=AD/TAND(B)
      AB=AG+GB
      EF=AE/TAND(A)
      HO=ED/TAND(C)
      DP=EF+HO+W
      PC=AB-DP
      IF(PC.LE.0.0)PC=0.0
      ARPRC=PC**2.*TAND(B)/4.
      VOLAS=(AROSC-ARPRC)*UIL
      RETURN
      END
```

```
      SUBROUTINE CYCLE(ST1,ST2,SCC,ASA,RK,TVS,BC,WD,WS,CLT,
     1  DT,BPT,TT,TCT,WT)
      SM=(ST2-ST1)/30.
      AST=(ASA*SM+SCC)
      ACT=(AST+DT+BPT)*RK
      NOC=(TVS/BC)
      TCT=FLOAT(NOC)*ACT
      WT=WD/WS+CLT
      TT=TCT+WT
      RETURN
      END
```

```
      SUBROUTINE VOLKEY(DLDIST,A,FA,CABHT,CABRAD,H,CUT,
     1   BOTKEY,IFLAG,VOL)
      DEPTH=H
      IF(IFLAG.EQ.1)DEPTH=DEPTH/2.
      THTAN=TAND(FA)
      DIGTAN=CABHT/(DLDIST-CABRAD)
      OF=DLDIST+CUT+DEPTH/THTAN
      OJ=DEPTH/TAND(FA)
      XBROW=OJ
      XINT=OF-CABRAD-((DEPTH+CABHT)/DIGTAN)
      IF(XINT.GT.CUT)XINT=CUT
      UHT=CUT*DIGTAN
      LHT=DEPTH-UHT
      TOPKEY=(DEPTH/TAND(A))*2.0+BOTKEY
      MIDKEY=BOTKEY+(LHT/DEPTH)*(TOPKEY-BOTKEY)
      C=-XINT*DIGTAN
      BXLONG=DEPTH/THTAN-C/(THTAN-DIGTAN)
      IF(XINT.LE.0.0) GO TO 10
      IF(XINT.LE.OJ)GO TO 11
      IF(XINT.GE.OJ)GO TO 12
10    VOL=(BXLONG+CUT)*UHT*(TOPKEY+MIDKEY)/4.0
      GO TO 13
11    VOL=CUT*UHT*(TOPKEY+MIDKEY)/4.+((DEPTH**2)
     1  *(TOPKEY+BOTKEY))/(4.0*THTAN)-(XBROW-XINT)
     1  *LHT*((BOTKEY+MIDKEY)/4.0)
      GO TO 13
12    AREA=DEPTH*(TOPKEY+BOTKEY)/2.0
      XBROW=OJ
      VOL=(XBROW+CUT-XINT)*AREA/2.0+(XINT-XBROW)*AREA+
     1  XBROW*AREA/2.0
13    RETURN
      END
```

```
      SUBROUTINE VOLCUT(DLDIST,I,JI,A,B,FA,CABHT,CABRAD,H,CT,CUT,
     1  SF,W,SEW,BOTKEY,IFLAG,RHVOL,NTP,VOL)
      EW=SEW
      DEPTH=H
      IF(IFLAG.EQ.1)DEPTH=DEPTH/2.
      THTAN=TAND(FA)
      DIGTAN=CABHT/(DLDIST-CABRAD)
      OF=DLDIST+CUT+DEPTH/THTAN
      OJ=DEPTH/TAND(FA)
      XINT=OF-CABRAD-((DEPTH+CABHT)/DIGTAN)
      IF(XINT.GT.CUT)XINT=CUT
      XBROW=OJ
      UHT=CUT*DIGTAN
      LHT=DEPTH-UHT
      TOPKEY=(DEPTH/TAND(A))*2.0+BOTKEY
      MIDKEY=BOTKEY+(LHT/DEPTH)*(TOPKEY-BOTKEY)
      WIDTH=W-TOPKEY
      C=-XINT*DIGTAN
      BXLONG=DEPTH/THTAN-C/(THTAN-DIGTAN)
      IF(XINT.LE.0)GO TO 10
      IF(XINT.LE.OJ) GO TO 11
      IF(XINT.GT.OJ)GO TO 12
10    Z1ARE1=UHT*CUT/2.
      Z1ARE2=UHT*BXLONG/2.
      Z1TVOL=(Z1ARE1+Z1ARE2)*WIDTH
      XSIDE=UHT**2.*(TOPKEY-BOTKEY-DEPTH/TAND(A))/(2.*DEPTH)
      Z2TVOL=XSIDE*((CUT+BXLONG)/2.0
      VOL=(Z1TVOL+2.*Z2TVOL)*SF
      RETURN
11    Z1ARE1=UHT*CUT/2.
      Z1AR23=DEPTH*OJ/2.
      Z1ARE3=(DEPTH-UHT)*(XBROW-XINT)/2.0
      Z1VOL=(Z1ARE1+Z1AR23-Z1ARE3)*WIDTH
      XSIDE=UHT**2/(2.*TAND(A))
      Z2VOL1=XSIDE*CUT/2.0
      TXSIDE=DEPTH**2./(2.*TAND(A))
      Z2VOL2=TXSIDE*XBROW/2.
      Z2VOL3=(TXSIDE-XSIDE)*(XBROW-XINT)/2.
      Z2TVOL=Z2VOL1+Z2VOL2-Z2VOL3
      VOL=(Z1VOL+2.*Z2TVOL)*SF
      RETURN
12    Z1ARE1=DEPTH*(XBROW+CUT-XINT)/2.
      Z1ARE2=DEPTH*(XINT-XBROW)
      Z1ARE3=DEPTH*(XBROW)/2.0
      Z1TVOL=(Z1ARE1+Z1ARE2+Z1ARE3)*WIDTH
      XSIDE=DEPTH**2./(2.*TAND(A))
      Z2VOL1=XSIDE*(XBROW+CUT-XINT)/2.
      Z2VOL2=XSIDE*(XINT-XBROW)
      Z2VOL3=XSIDE*XBROW/2.
      Z2TVOL=Z2VOL1+Z2VOL2+Z2VOL3
      VOL=(Z1TVOL+2.*Z2TVOL)*SF
```

```
      IF(I.NE.NTP)RETURN
      EW1=DEPTH/TAND(A)
      IF(EW.LT.EW1)GO TO 13
      EVB1=(DEPTH**2/(2.*TAND(A))+(EW-DEPTH/TAND(A))*DEPTH
     1  +DEPTH**2/(TAND(B)*2.))*CUT
      GO TO 15
13    EVB1=(EW*DEPTH+DEPTH**2/(2.*TAND(B))-DEPTH**2/(2.*TAND(A)))*CUT
15    IF((IFLAG.EQ.1).AND.(I.LE.JI))EVB=EVB1
      IF((IFLAG.EQ.1).AND.(I.GT.JI))EVB=RHVOL-EVB1
      IF(IFLAG.EQ.0)EVB=RHVOL
      VOL=VOL+EVB
      RETURN
      END
```

```
C THIS IS THE COMPUTER PROGRAM FOR PULLBACK OPERATION
C PROGRAMED BY KADRI DAGDELEN
      DIMENSION DDFDF(0/15),DDFH(0/15),DTXS(15,0/30),TVS(0/15)
     1  ,VOL(0/15),ASA(15),TT(15),TCT(15),WD(15),WT(15)
     1  ,SA1(15),SA2(15)
      REAL JF
      DOUBLE PRECISION MT
C     INITILIZE VARIABLES
C
      DATA TTSFP,TTSFK/2*0.0/,TVSS,TTSS/2*0.0/,TVS/16*
     1  0.0/,VOL(0)/0.0/,CONV/57.2957/,TVSFK,TVSFP
     1  /2*0.0/,TWSA/0.0/,TOTCT,TOTWT/2*0.0/
      OPEN (UNIT=8,FILE='DRG1.DAT',ACCESS='SEQIN')
      READ(8,100) H,CT,CD,A,B,C,SF,X,W,WK
100   FORMAT (10F)
C
      READ(8,110)MT
110   FORMAT(A10)
      READ(8,120)DR,BC,CABHT,CABRAD,P
120   FORMAT(5F)
      READ(8,130)NPK,NTP,N
130   FORMAT(3I)
      READ(8,140)(DDFDF(J),DDFH(J),J=1,NTP)
140   FORMAT(2F)
      READ (8,150)DT,BPT,ST1,ST2,SCC,WS,CLT
150   FORMAT(7F)
      READ(8,160)SH,AV,JF,RF,FF
160   FORMAT(5F)
      READ(8,171)IFLAG
171   FORMAT(I)
      IF(IFLAG.EQ.0)GO TO 174
      READ(8,172)NFSIKP,NFSLKP,NFSTP
172   FORMAT(3I)
      READ(8,173)(DDFDF(J),DDFH(J),J=NFSIKP,NFSTP)
173   FORMAT(2F)
174   IF(IFLAG.EQ.0)NFSTP=NTP
      IF(IFLAG.EQ.1)GO TO 176
      TOPKEY=(H/TAND(A))*2.+WK
      IF(TOPKEY.LE.W-5.)GO TO 176
      WRITE(4,175)
175   FORMAT(1X,10X,'OVERBURDEN IS TOO DEEP',/
     1  1X,10X,'IT WILL BE MINED IN TWO LIFTS',/
     1  1X,10X,'ENTER NEW SET OF DRAGLINE ',/
     1  1X,10X,'POSITIONS FOR SECOND LIFT')
      STOP
176   DDFH(0)=DDFH(NTP)
      DDFDF(0)=-X+DDFDF(NTP)
      SF=1.0+SF/100.0
      BC=BC*FF*27.
C
C CALCULATE AVERAGE SWING ANGLE FOR PRIMARY MACHINE
```

```
C
      JM=1
      M=0
      MI=NPK
      JI=NTP
177   IF((IFLAG.EQ.1).AND.(M.EQ.JI))JM=NFSIKP
      IF((IFLAG.EQ.1).AND.(M.EQ.JI))NTP=NFSTP
      IF((IFLAG.EQ.1).AND.(M.EQ.JI))NPK=NFSLKP
      DO 10 K=JM,NTP
      M=K
      SA1(K)=ACOS((DDFDF(K)-P+X)/DR)*CONV
      SA2(K)=ACOS((DDFDF(K)-P)/DR)*CONV
      ASA(K)=(SA1(K)+SA2(K))/2.0
C CALCULATE VOLUME SPOILEDED FROM A GIVEN POSITION
      IF(K.GT.NPK)GO TO 20
C
C DRAGLINE IS IN KEY CUT POSITION
      RK=1.5
      TVS(JI)=0.0
      TVSFK=TVSFK+TVS(K-1)
      CALL VOLKEY(DDFDF(K),A,CABHT,CABRAD,H,X,WK,IFLAG,VOL(K))
      VOL(K)=VOL(K)*SF
      VOL(K)=VOL(K)-TVSFK

      GO TO 30
C
C IN PRIME CUT POSITION; CALCULATE VOLUME REMOVED
C
20    RK=1.0
      TVS(NPK)=0.0
      TVSFP=TVSFP+TVS(K-1)
      CALL VOLCUT (DDFDF(K),A,CABHT,CABRAD,H,X,W,WK,IFLAG,
     1  VOL(K))
      VOL(K)=VOL(K)*SF
      VOL(K)=VOL(K)-TVSFP
C
30    TVS(K)=VOL(K)
C
C CALCULATE THE DISTANCE DRAGLINE WALKS TO A GIVEN POSITION
      WD(K)=SQRT((DDFDF(K)-DDFDF(K-1))**2+(DDFH(K)
     1  -DDFH(K-1))**2)
      CALL CYCLE (ST1,ST2,SCC,ASA(K),RK,TVS(K),BC,WD,WS,CLT,
     1  DT,BPT,TT(K),TCT(K),WT(K))
      TTSS=TTSS+TT(K)
      TOTCT=TOTCT+TCT(K)
      TOTWT=TOTWT+WT(K)
C
C     FIND TOTAL VOLUME SPOILED FOR THE SEGMENT
C
      TVSS=TVSS+TVS(K)
      TWSA=TWSA+ASA(K)*TVS(K)
```

```
10    CONTINUE
      TVSFK=0.0
      TVSFP=0.0
      IF((IFLAG.EQ.1).AND.(M.EQ.JI))GO TO 177
      FASA=TWSA/TVSS
C
C CALCULATE DRAGLINE PRODUCTION
C
      TNOC=TVSS/BC
      FACT=TTSS/TNOC
      NOCPH=3600.0/FACT
      DPPH=NOCPH*BC
C
C DRAGLINE PRODUCTION FOR PRIME MACHINE IS KNOWN
C CALCULATE PULL BACK MACHINE REACH AND BUCKET CAPACITY
C
C     REACH OF THE SECOND MACHINE
C
      ESR=(SQRT(DR*DR-X*X)+DR)/2.0-P
C CALCULATE THE BUCKET CAPACITY
C
C     AMOUNT OF MATERIAL TO BE REHANDLE BY THE PULL BACK MACHI
C
      UAS=W*H*SF
C     CONSTANTS OF SECOND DEGREE EQUATION
      CA=3*TAND(B)/4.
      CB=TAND(B)*(ESR-H/TAND(A)-CT/TAND(C)-CT/TAND(B)+W/2.)
      CC=W*TAND(B)*(ESR-H/TAND(A)-CT/TAND(C))+(CT*CT/2.)
     1  *(1/TAND(B)+1/TAND(C))-W*W*TAND(B)/4.-UAS
      YK=SQRT(CB*CB-4.*CA*CC)
C     THE ROOTS OF THE EQUATION
      WX=(-CB+YK)/(2.0*CA)
      CONST3=WX*TAND(B)*(ESR-H/TAND(A)-CT/TAND(C)+3*WX/4.
     1  +W/4.0)
      CONST4=WX*CT-(CT*CT/2.0)*(1/TAND(B)+1/TAND(C))
      PBDR=ESR-H/TAND(A)-CT*(1/TAND(B)+1/TAND(C))+
     1  (7*WX+W)/4.0
C
C     REHANDLE VOLUME FOR UNIT LENGTH
C
      RHA=(CONST3-CONST4)
      TOTSA=W*H*SF
C
C     PERCENT REHANDLE IN TOTAL PRODUCTION
      PERREH=RHA/TOTSA
C
C     AMOUNT OF MATERIAL REHANDLED BY DOZER
      DRV=((WX+W)*(WX+W)/16.)*TAND(B)*X
      DPERRH=DRV/(W*H*X*SF)
      DOPPH=DPPH*DPERRH/27.
C
```

```
C      HOURLY PRODUCTION REQUIRED FROM PULL BACK MACHINE
C
       PBMPPH=PERREH*DPPH/27.
C
C      ASSUME 180.0 SWING ANGLE FOR PULL BACK MACHINE
C      CALCULATE CYCLE TIME
C
       PBASA=180.0
       SM=(ST2-ST1)/30.0
       PBAST=(PBASA*SM+SCC)
       ACT=(PBAST+DT+BPT)
C      CALCULATE BUCKET CAPACITY FOR THE SECOND MACHINE
C
C      CALCULATE HOW MANY CYCLES IN HOUR
       NOCPH=3600./ACT
       PBBC=PBMPPH/NOCPH
       PERREH=PERREH*100.0
       DPERPH=DPERRH*100.0
       WRITE(4,40)PBDR,PBBC,DOPPH,PERREH,DPERRH
40     FORMAT(10X,'REQUIRED MACHINE SPECIFICATIONS'/
      1 1X,24X,'FOR'/
      1 1X,16X,'PULL BACK MACHINE'//
      1 1X,10X,'REQUIRED REACH',4X,':',F10.2,2X,'FT'//
      1 1X,10X,'BUCKET CAPACITY',3X,':',F10.2,2X,'CUBIC YARD'//
      1 1X,10X,'DOZER PRODUCTION',2X,':',F10.2,2X,'CUBIC YARD'//
      1 1X,10X,'PULL BACK MACHINE % REHANDLE :',F10.2//
      1 1X,10X,'DOZER % REHANDLE',2X,':',F10.2)
       END
```

```
      SUBROUTINE CYCLE(ST1,ST2,SCC,ASA,RK,TVS,BC,WD,WS,CLT,
     1  DT,BPT,TT,TCT,WT)
      SM=(ST2-ST1)/30.
      AST=(ASA*SM+SCC)
      ACT=(AST+DT+BPT)*RK
      NOC=(TVS/BC)
      TCT=FLOAT(NOC)*ACT
      WT=WD/WS+CLT
      TT=TCT+WT
      RETURN
      END
```

```
      SUBROUTINE VOLKEY(DLDIST,A,CABHT,CABRAD,H,CUT,BOTKEY
     1  ,IFLAG,VOL)
      DEPTH=H
      IF(IFLAG.EQ.1)DEPTH=DEPTH/2
      THTAN=TAND(A)
      DIGTAN=CABHT/(DLDIST-CABRAD)
      OF=DLDIST+CUT+DEPTH/THTAN
      OJ=DEPTH/TAND(A)
      XBROW=OJ
      XINT=OF-CABRAD-((DEPTH+CABHT)/DIGTAN)
      IF(XINT.GT.CUT)XINT=CUT
      UHT=CUT*DIGTAN
      LHT=DEPTH-UHT
      TOPKEY=(DEPTH/THTAN)*2.0+BOTKEY
      MIDKEY=BOTKEY+(LHT/DEPTH)*(TOPKEY-BOTKEY)
      C=-XINT*DIGTAN
      BXLONG=DEPTH/THTAN-C/(THTAN-DIGTAN)
      IF(XINT.LE.0.0) GO TO 10
      IF(XINT.LE.OJ)GO TO 11
      IF(XINT.GE.OJ)GO TO 12
10    VOL=(BXLONG+CUT)*UHT*(TOPKEY+MIDKEY)/4.0
      GO TO 13
11    VOL=CUT*UHT*(TOPKEY+MIDKEY)/4.+((DEPTH**2)
     1  *(TOPKEY+BOTKEY))/(4.0*THTAN)-(XBROW-XINT)
     1  *LHT*((BOTKEY+MIDKEY)/4.0)
      GO TO 13
12    AREA=DEPTH*(TOPKEY+BOTKEY)/2.0
      XBROW=OJ
      VOL=(XBROW+CUT-XINT)*AREA/2.0+(XINT-XBROW)*AREA+
     1  XBROW*AREA/2.0
13    RETURN
      END
```

```
      SUBROUTINE VOLCUT(DLDIST,A,CABHT,CABRAD,H,CUT,W,
     1  BOTKEY,IFLAG,VOL)
      DEPTH=H
      IF(IFLAG.EQ.1)DEPTH=DEPTH/2
      THTAN=TAND(A)
      DIGTAN=CABHT/(DLDIST-CABRAD)
      OF=DLDIST+CUT+DEPTH/THTAN
      OJ=DEPTH/TAND(A)
      XINT=OF-CABRAD-((DEPTH+CABHT)/DIGTAN)
      IF(XINT.GT.CUT)XINT=CUT
      XBROW=OJ
      UHT=CUT*DIGTAN
      LHT=DEPTH-UHT
      TOPKEY=(DEPTH/THTAN)*2.0+BOTKEY
      MIDKEY=BOTKEY+(LHT/DEPTH)*(TOPKEY-BOTKEY)
      WIDTH=W-TOPKEY
      C=-XINT*DIGTAN
      BXLONG=DEPTH/THTAN-C/(THTAN-DIGTAN)
      IF(XINT.LE.0)GO TO 10
      IF(XINT.LE.OJ) GO TO 11
      IF(XINT.GT.OJ)GO TO 12
10    Z1ARE1=UHT*CUT/2.
      Z1ARE2=UHT*BXLONG/2.
      Z1TVOL=(Z1ARE1+Z1ARE2)*WIDTH
      XSIDE=UHT**2.*XBROW/(2*DEPTH)
      Z2TVOL=XSIDE*(CUT+BXLONG)/2.0
      VOL=Z1TVOL+2.*Z2TVOL
      RETURN
11    Z1ARE1=UHT*CUT/2.
      Z1AR23=DEPTH*OJ/2.
      Z1ARE3=(DEPTH-UHT)*(XBROW-XINT)/2.0
      Z1VOL=(Z1ARE1+Z1AR23-Z1ARE3)*WIDTH
      XSIDE=UHT**2/(2.*TAND(A))
      Z2VOL1=XSIDE*CUT/2.0
      TXSIDE=DEPTH**2./(2.*TAND(A))
      Z2VOL2=TXSIDE*XBROW/2.
      Z2VOL3=(TXSIDE-XSIDE)*(XBROW-XINT)/2.
      Z2TVOL=Z2VOL1+Z2VOL2-Z2VOL3
      VOL=Z1VOL+2.*Z2TVOL
      RETURN
12    Z1ARE1=DEPTH*(XBROW+CUT-XINT)/2.
      Z1ARE2=DEPTH*(XINT-XBROW)
      Z1ARE3=DEPTH*(XBROW)/2.0
      Z1TVOL=(Z1ARE1+Z1ARE2+Z1ARE3)*WIDTH
      XSIDE=DEPTH*XBROW/2.
      Z2VOL1=XSIDE*(XBROW+CUT-XINT)/2.
      Z2VOL2=XSIDE*(XINT-XBROW)
      Z2VOL3=XSIDE*XBROW/2.
      Z2TVOL=Z2VOL1+Z2VOL2+Z2VOL3
      VOL=Z1TVOL+2.*Z2TVOL
      RETURN
```

END

```
C      THIS IS THE COMPUTER PROGRAM FOR SIMULATION OF PULLBACK
C      OPERATION BY TWO MACHINES.
C      PROGRAMMED BY KADRI DAGDELEN

C      PROGRAM NAME : PUL2.FOR

       DIMENSION DDFDF(0/15),DDFH(0/15),DTXS(15,0/30),TVS(0/15)
       DIMENSION VOL(0/15),ASA(15),TT(15),TCT(15),WD(15)
       DIMENSION WT(15),DPPH(2),PCH(2),PCKH(2),LR(2),DIC(2)
       DIMENSION DOL(2),ITIP(2),MCPCY(2),SH(2),AP(2),CCYD(2)
       DIMENSION OCH(2),AV(2),JF(2),OWCH(2),CPH(2),OCCYD(2)
       DIMENSION OWCCYD(2),ET(2)
       REAL ITIP,LR,LCH,MCH,JF,MCPCY
       DOUBLE PRECISION MT1,MT2
C      INITIALIZE VARIABLES
       DATA TTSFP,TTSFK/2*0.0/,TVSS,TTSS/2*0.0/,TVS/16*0.0/
      1  ,VOL(0)/0.0/,CONV/57.2957/,TVSFP,TVSFK/2*0.0/,TOWCH,
      1   TOCH/2*0.0/
       OPEN(UNIT=11,FILE='PULDAT',ACCESS='SEQIN')
       READ (11,100) H,CT,CD,A,B,C,SF,X,W,WK,RF
100    FORMAT (11F)
       READ (11,110) MT1
110    FORMAT (A10)
       READ (11,120) DR,BC,FF,CABHT,CABRAD,P
120    FORMAT (6F)
       READ (11,130) NPK,NTP,N
130    FORMAT (3I)
       READ (11,140) (DDFDF(J),DDFH(J), J=1,NTP)
140    FORMAT (2F)
       READ (11,150) DT,BPT,ST1,ST2,SCC,WS,CLT
150    FORMAT (7F)
       READ (11,160) (SH(K),AV(K),JF(K),K=1,2)
160    FORMAT (3F)
       READ (11,170) MT2
170    FORMAT (A10)
       READ (11,180) PBDR,PBBC,PBFF
180    FORMAT (6F)
       READ (11,190) PBDT,PBBPT,PBST1,PBST2,PBSCC,PBWS,PBCLT
190    FORMAT (7F)
       READ (11,200) (PCH(I),PCKH(I),MCPCY(I),LR(I),DIC(I),
      1  DOL(I),ITIP(I), I=1,2)
200    FORMAT (7F)
       READ (11,210) DOCPH,DOWCPH
210    FORMAT (2F)
       READ(11,171)IFLAG
171    FORMAT(I)
       IF(IFLAG.EQ.0)GO TO 174
       READ(11,172)NFSIKP,NFSLKP,NFSTP
172    FORMAT(3I)
       READ(11,173)(DDFDF(J),DDFH(J),J=NFSIKP,NFSTP)
173    FORMAT(2F)
```

```
174    IF(IFLAG.EQ.0)NFSTP=NTP
       IF(IFLAG.EQ.1)GO TO 176
       TOPKEY=(H/TAND(A))*2.+WK
       IF(TOPKEY.LE.W-5.)GO TO 176
       WRITE(4,175)
175    FORMAT(1X,10X,'OVERBURDEN IS TOO DEEP',/
      1  1X,10X,'IT WILL BE MINED IN TWO LIFTS',/
      1  1X,10X,'ENTER NEW SET OF DRAGLINE ',/
      1  1X,10X,'POSITIONS FOR SECOND LIFT')
       STOP
176    PBSH=SH(2)
       PBAV=AV(2)
       PBJF=JF(2)
       DDFH(0)=DDFH(NTP)
       DDFDF(0)=-X+DDFDF(NTP)
       SF=1.0+SF/100.
       BC=BC*FF*27.
       PBBC=PBBC*FF*27.
C      CALCULATE AVERAGE SWING ANGLE FOR PRIMARY MACHINE
       JM=1
       M=0
       MI=NPK
       JI=NTP
177    IF((IFLAG.EQ.1).AND.(M.EQ.JI))JM=NFSIKP
       IF((IFLAG.EQ.1).AND.(M.EQ.JI))NTP=NFSTP
       IF((IFLAG.EQ.1).AND.(M.EQ.JI))NPK=NFSLKP
       DO 10 K=JM,NTP
       M=K
       SA1=ACOS((DDFDF(K)-P+X)/DR)*CONV
       SA2=ACOS((DDFDF(K)-P)/DR)*CONV
       ASA(K)=(SA1+SA2)/2.0
C      CALCULATE VOLUME SPOILED FROM A GIVEN POSITION
       IF (K.GT.NPK) GO TO 20
C      DRAGLINE IS IN KEYCUT POSITION
       RK=1.5
       TVS(JI)=0.0
       TVSFK=TVSFK+TVS(K-1)
       CALL VOLKEY(DDFDF(K),A,CABHT,CABRAD,H,X,WK,IFLAG,VOL(K))
       VOL(K)=VOL(K)*SF
       VOL(K)=VOL(K)-TVSFK
       GO TO 30
C      IN PRIME CUT POSITION; CALCULATE VOLUME REMOVABLE
20     RK=1.0
       TVS(NPK)=0.0
       TVSFP=TVSFP+TVS(K-1)
       CALL VOLCUT(DDFDF(K),A,CABHT,CABRAD,H,X,W,WK,IFLAG,
      1  VOL(K))
       VOL(K)=VOL(K)*SF
       VOL(K)=VOL(K)-TVSFP
30     TVS(K)=VOL(K)
C      CALCULATE THE DISTANCE DRAGLINE WALKS TO A GIVEN
```

```
C       POSITION
        WD(K)=SQRT((DDFDF(K)-DDFDF(K-1))**2+(DDFH(K)
      1   -DDFH(K-1))**2)
        CALL CYCLE(ST1,ST2,SCC,ASA(K),RK,TVS(K),BC,WD,WS,CLT,
      1   DT,BPT,TT(K),TCT(K),WT(K))
        TTSS=TTSS+TT(K)
        TOTCT=TOTCT+TCT(K)
        TOTWT=TOTWT+WT(K)
C       FIND TOTAL VOLUME SPOILED FOR SEGMENT
        TVSS=TVSS+TVS(K)
        TWSA=TWSA+ASA(K)*TVS(K)
10      CONTINUE
        TVSFK=0.0
        TVSFP=0.0
        IF((IFLAG.EQ.1).AND.(M.EQ.JI))GO TO 177
        FASA=TWSA/TVSS
C       CALCULATE DRAGLINE PRODUCTION IN HOUR
        TNOC=TVSS/BC
        FACT=TTSS/TNOC
        NOCPH=3600.0/FACT
        DPPH(1)=NOCPH*BC/27.
C       ASSUME 180 DEGREE SWING ANGLE FOR PULLBACK MACHINE
C       CALCULATE PRODUCTION OF THE SECOND MACHINE
        PBASA=180.0
        PBSM=(PBST2-PBST1)/30.0
        PBAST=(PBASA*PBSM+PBSCC)
        PBACT=PBAST+PBDT+PBBPT
        NOCPH=3600.0/PBACT
        DPPH(2)=PBBC*NOCPH/27.
        PBAP=PBSH**PBAV*PBJF*DPPH(2)
C       CALCULATE COST OF PRODUCTION FOR TWO DRAGLINES AND THE
C       DOZER
        DO 220 L=1,2
        PCOSTH=PCH(L)*PCKH(L)
        MCH=MCPCY(L)*DPPH(L)
        LCH=3.0*LR(L)
        OCH(L)=PCOSTH+MCH+LCH
        DCY=DIC(L)/DOL(L)
        DCH=DCY/SH(L)
        AVI=DIC(L)*(DOL(L)+1.0)/(2.0*DOL(L))
        ITI=ITIP(L)*AVI
        ITIH=ITI/SH(L)
        OWCH(L)=DCH+ITIH
        ET(L)=SH(L)*AV(L)*JF(L)
        AP(L)=ET(L)*DPPH(L)
        OCCYD(L)=OCH(L)/DPPH(L)
        OWCCYD(L)=OWCH(L)/DPPH(L)
        CCYD(L)=OWCCYD(L)+OCCYD(L)
        TOCH=TOCH+OCH(L)
        TOWCH=TOWCH+OWCH(L)
220     CONTINUE
```

```
      TOCH=TOCH+DOCPH
      TOWCH=TOWCH+DOWCPH
C     CALCULATE COAL TONNAGE
      AD=(AP(1)*27.)/H
      CV=AD*CT
      CTON=CV*CD/(2000.0)*RF
      CTHR=CTON/SH(1)
      TOCTON=TOCH/CTHR
      TOWCTN=TOWCH/CTHR
      TCTON=TOCTON+TOWCTN
      TOWCYD=TOWCH/(DPPH(1)+DPPH(2))
      TOCCYD=TOCH/(DPPH(1)+DPPH(2))
      TOTCH=TOCH+TOWCH
      TCCYD=TOTCH/(DPPH(1)+DPPH(2))
      CALL REHAND(H,CT,SF,P,W,A,B,C,DR,X,PERREH,DPERRH)
      TVS(MI)=TVSLKP
      TVS(NPK)=VSFFKP
      BC=BC/(FF*27)
      PBBC=PBBC/(FF*27.)
      SF=SF*100.
      PERREH=PERREH*100.
      DPERRH=DPERRH*100.
      WRITE (4,300) H,CT,A
300   FORMAT (1X,23X,'PROPERTY CHARACTERISTICS'//
     1  1X,10X,'OVERBURDEN HEIGHT',8X,':',F10.2,2X,'FT'/
     1  1X,10X,'COAL THICKNESS',11X,':',F10.2,2X,'FT'/
     1  1X,10X,'HIGH WALL ANGLE',10X,':',F10.2,2X,
     1  'DEGREES')
      WRITE (4,310) B,C,SF,RF,W,X
310   FORMAT (1X,10X,'SPOIL ANGLE OF REPOSE',4X,':',F10.2,
     1  2X,'DEGREES'/1X,10X,'COAL HIGHWALL ANGLE',6X,':',
     1  F10.2,2X,'DEGREES'/1X,10X,'SWELL FACTOR',13X,':',F10.2,
     1  2X,'%',/1X,10X,'COAL RECOVERY',12X,':',F10.2,2X,
     1  '%',/1X,10X,'PIT WIDTH',16X,':',F10.2,2X,'FT',/
     1  1X,10X,'CUT LENGTH',15X,':',F10.2,2X,'FT'//)
      WRITE (4,320)
320   FORMAT (23X,'MACHINE CHARACTERISTICS'//
     1  1X,21X,'-----------------------',/
     1  1X,27X,'DRAGLINE 1'/
     1  1X,21X,'-----------------------'/)
      WRITE (4,330) MT1,DR,BC,SH(1),AV(1),JF(1)
330   FORMAT (1X,10X,'DRAGLINE TYPE',12X,':',4X,A10/
     1  1X,10X,'DRAGLINE REACH',11X,':',F10.2,2X,'FT'/
     1  1X,10X,'BUCKET CAPACITY',10X,':',F10.2,2X,'CUBIC YD'/
     1  1X,10X,'SCHEDULED HOURS',10X,':',F10.2,2X,'HOURS'/
     1  1X,10X,'MECHANICAL AVAILABILITY',2X,':',F10.2,2X,'%'/
     1  1X,10X,'JOB FACTOR',15X,':',F10.2,2X,'%')
      WRITE (4,340) FASA,FACT,DPPH(1),AP(1)
340   FORMAT (1X,10X,'AVERAGE SWING ANGLE',6X,':',F10.2,2X,
     1  'DEGREES',/
     1  1X,10X,'AVERAGE CYCLE TIME',7X,':',F10.2,2X,'SECONDS',/
```

```
     1  1X,10X,'PRODUCTION RATE',10X,':'F10.2,2X,'CU. YD/HR',/
     1  1X,10X,'TOTAL VOLUME SPOILED',5X,':',F10.1,2X,
     1  'CUBIC YD')
      WRITE (4,350)  CCYD(1)
350   FORMAT (1X,10X,'COST',21X,':',F10.2,2X,'$/CUBIC YD'/)
      WRITE (4,360)
360   FORMAT(1X,21X,'----------------------'/
     1  1X,27X,'DRAGLINE 2',/
     1  1X,21X,'----------------------'/)
      WRITE (4,330) MT2,PBDR,PBBC,PBSH,PBAV,PBJF
      WRITE (4,340) PBASA,PBACT,DPPH(2),AP(2)
      WRITE (4,350) CCYD(2)
      WRITE(4,370)
370   FORMAT(23X,'PRODUCTION SUMMARY',//)
      WRITE(4,380)CTON
380   FORMAT(1X,10X,'TOTAL COAL MINED',9X,':',F10.2,2X,
     1  'TON/YEAR',/)
      WRITE(4,390)
390   FORMAT(1X,10X,'PERCENT REHANDLE')
      WRITE(4,400)PERREH,DPERRH
400   FORMAT(1X,14X,'PULL BACK MACHINE',4X,':',
     1  F10.2,2X,'%',/
     1  1X,14X,'DOZER',16X,':',F10.2,2X,'%',/)
      WRITE(4,410)TCCYD,TCTON
410   FORMAT(1X,10X,'TOTAL COST',15X,':',F10.2,2X,'$/CU. YD'/
     1  1X,35X,':'F10.2,2X,'$/TON')
      END
```

```
      SUBROUTINE CYCLE(ST1,ST2,SCC,ASA,RK,TVS,BC,WD,WS,CLT,
     1  DT,BPT,TT,TCT,WT)
      SM=(ST2-ST1)/30.
      AST=(ASA*SM+SCC)
      ACT=(AST+DT+BPT)*RK
      NOC=(TVS/BC)
      TCT=FLOAT(NOC)*ACT
      WT=WD/WS+CLT
      TT=TCT+WT
      RETURN
      END
```

```
      SUBROUTINE REHAND(H,CT,SF,P,W,A,B,C,DR,X,PERREH,DPERRH)
      ESR=(SQRT(DR*DR-X*X)+DR)/2.-P
      UAS=W*H*SF
      CA=3.*TAND(B)/4.
      CB=TAND(B)*(ESR-H/TAND(A)-CT/TAND(C)-CT/TAND(B)+W/2.)
      CC=W*TAND(B)*(ESR-H/TAND(A)-CT/TAND(C))+(CT*CT/2.)
     1  *(1/TAND(B)+1/TAND(C))-W*W*TAND(B)/4.-UAS
      YK=SQRT(CB*CB-4.*CA*CC)
      WX=(-CB+YK)/(2.*CA)
      CONST3=WX*TAND(B)*(ESR-H/TAND(A)-CT/TAND(C)+3.*WX/4.
     1  +W/4.0)
      CONST4=WX*CT-(CT*CT/2.0)*(1/TAND(B)+1/TAND(C))
      RHA=(CONST3-CONST4)
      TOTSA=W*H*SF
      PERREH=RHA/TOTSA
      DRV=((WX+W)**2/16.)*TAND(B)*X
      DPERRH=DRV/(W*H*X*SF)
      RETURN
      END
```

```
      SUBROUTINE VOLKEY(DLDIST,A,CABHT,CABRAD,H,CUT,BOTKEY
     1  ,IFLAG,VOL)
      DEPTH=H
      IF(IFLAG.EQ.1)DEPTH=DEPTH/2.
      THTAN=TAND(A)
      DIGTAN=CABHT/(DLDIST-CABRAD)
      OF=DLDIST+CUT+DEPTH/THTAN
      OJ=DEPTH/TAND(A)
      XBROW=OJ
      XINT=OF-CABRAD-((DEPTH+CABHT)/DIGTAN)
      IF(XINT.GT.CUT)XINT=CUT
      UHT=CUT*DIGTAN
      LHT=DEPTH-UHT
      TOPKEY=(DEPTH/THTAN)*2.0+BOTKEY
      MIDKEY=BOTKEY+(LHT/DEPTH)*(TOPKEY-BOTKEY)
      C=-XINT*DIGTAN
      BXLONG=DEPTH/THTAN-C/(THTAN-DIGTAN)
      IF(XINT.LE.0.0) GO TO 10
      IF(XINT.LE.OJ)GO TO 11
      IF(XINT.GE.OJ)GO TO 12
10    VOL=(BXLONG+CUT)*UHT*(TOPKEY+MIDKEY)/4.0
      GO TO 13
11    VOL=CUT*UHT*(TOPKEY+MIDKEY)/4.+((DEPTH**2)
     1  *(TOPKEY+BOTKEY))/(4.0*THTAN)-(XBROW-XINT)
     1  *LHT*((BOTKEY+MIDKEY)/4.0)
      GO TO 13
12    AREA=DEPTH*(TOPKEY+BOTKEY)/2.0
      XBROW=OJ
      VOL=(XBROW+CUT-XINT)*AREA/2.0+(XINT-XBROW)*AREA+
     1  XBROW*AREA/2.0
13    RETURN
      END
```

```
      SUBROUTINE VOLCUT(DLDIST,A,CABHT,CABRAD,H,CUT,W,
     1  BOTKEY,IFLAG,VOL)
      DEPTH=H
      IF(IFLAG.EQ.1)DEPTH=DEPTH/2.
      THTAN=TAND(A)
      DIGTAN=CABHT/(DLDIST-CABRAD)
      OF=DLDIST+CUT+DEPTH/THTAN
      OJ=DEPTH/TAND(A)
      XINT=OF-CABRAD-((DEPTH+CABHT)/DIGTAN)
      IF(XINT.GT.CUT)XINT=CUT
      XBROW=OJ
      UHT=CUT*DIGTAN
      LHT=DEPTH-UHT
      TOPKEY=(DEPTH/THTAN)*2.0+BOTKEY
      MIDKEY=BOTKEY+(LHT/DEPTH)*(TOPKEY-BOTKEY)
      WIDTH=W-TOPKEY
      C=-XINT*DIGTAN
      BXLONG=DEPTH/THTAN-C/(THTAN-DIGTAN)
      IF(XINT.LE.0)GO TO 10
      IF(XINT.LE.OJ) GO TO 11
      IF(XINT.GT.OJ)GO TO 12
10    Z1ARE1=UHT*CUT/2.
      Z1ARE2=UHT*BXLONG/2.
      Z1TVOL=(Z1ARE1+Z1ARE2)*WIDTH
      XSIDE=UHT**2.*XBROW/(2*DEPTH)
      Z2TVOL=XSIDE*(CUT+BXLONG)/2.0
      VOL=Z1TVOL+2.*Z2TVOL
      RETURN
11    Z1ARE1=UHT*CUT/2.
      Z1AR23=DEPTH*OJ/2.
      Z1ARE3=(DEPTH-UHT)*(XBROW-XINT)/2.0
      Z1VOL=(Z1ARE1+Z1AR23-Z1ARE3)*WIDTH
      XSIDE=UHT**2/(2.*TAND(A))
      Z2VOL1=XSIDE*CUT/2.0
      TXSIDE=DEPTH**2./(2.*TAND(A))
      Z2VOL2=TXSIDE*XBROW/2.
      Z2VOL3=(TXSIDE-XSIDE)*(XBROW-XINT)/2.
      Z2TVOL=Z2VOL1+Z2VOL2-Z2VOL3
      VOL=Z1VOL+2.*Z2TVOL
      RETURN
12    Z1ARE1=DEPTH*(XBROW+CUT-XINT)/2.
      Z1ARE2=DEPTH*(XINT-XBROW)
      Z1ARE3=DEPTH*(XBROW)/2.0
      Z1TVOL=(Z1ARE1+Z1ARE2+Z1ARE3)*WIDTH
      XSIDE=DEPTH*XBROW/2.
      Z2VOL1=XSIDE*(XBROW+CUT-XINT)/2.
      Z2VOL2=XSIDE*(XINT-XBROW)
      Z2VOL3=XSIDE*XBROW/2.
      Z2TVOL=Z2VOL1+Z2VOL2+Z2VOL3
      VOL=Z1TVOL+2.*Z2TVOL
      RETURN
```

END