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Analytical Models for Bucket Wheel Excavator Mining Face Design

BY

Maurice E. Pinco

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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To Jeanine

Abstract

Unlike other mining units such as shovels and draglines, the Bucket Wheel Excavator (BWE) requires very detailed mine planning in order to realize its full potential. This mine planning can be more easily accomplished if a set of relationships describing the excavator's limits are available to the mine engineer. In additioin to mine planning, such a set of relationships can be used to aid in excavator selection.

This thesis sets out to develop and test a series of relationships to describe the limitations and applications of a BWE forming either a terrace cut or dropping cut.

To accomplish these objectives, a set of mathematical expressions have been developed to describe the inter-dependance between the BWE's design parameters and the mining face. These expressions were determined through the use of geometry. The numerous computations which were required to define the full range of limitations for a particular BWE was accomplished by using computer programs. The programs request the BWE design parameters from the user, then outputs in table form the slope limitations for these parameters. The accuracy of these relationships was tested replica of an O&K SH 630 compact BWE.

The results of this investigation showed that the relationships developed do accurately describe the

inter-relationships between the BWE design parameters and the mining face, and can be used with conficence.

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I would like to thank Jeanine for her support and encouragement throughout this trying time in our lives. Also to Kathie for allowing us to unburden ourselves during this time.

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List of Sysmbols Used

A	= The distance the excavator makes into the front face on each cut
ab	= The maximum depth of a slice extracted by the excavator on each slew of the digging wheel
CL	= Distance between the leading edge of the crawler, and the centre of rotation of the BWE
CW	= Distance between the outside edge of the crawler, and the BWE centreline of advance
D	= Digging wheel diameter, measured to the bucket cutting lips
D1	= Digging wheel diameter without buckets, at wheel rim
E	= Distance between the load boom pivot point and the centre of rotation of the BWE; can be positive or negative
F	= Safety distance between the crawler and the slope toe required to prevent crawler damage
F1/F2	= Distances used to determine F, or to define the distance between the load boom structure and the front slope crest
H	= Actual bench height presently being used
H1/H2/HS	= Intermediate bench heights required to find the distance between the digging wheel centre and the side slope crest, (used in the dropping cut)

Hdmax	= Maximum bench height to which the dropping cut can be used
HM	= Maximum elevation of the digging wheel centre above the crawler level
HT2	= Bench height from the crawler level to the crest of the second terrace
L	= The horizontal distance between the load boom pivot point and the crest of the second terrace on the front face, (also used in the dropping cut)
L1	= Horizontal distance of the actual side slope, projected onto the base plane the excavator crawlers rest on
L1ab	= The length of line L1 using a bench height of ab [Model C]
L2	= Horizontal distance of the side slope at some offset angle, θ, projected onto the base plane the excavator crawlers rest on
L2a/L2b/L2c	= Length of line L2 at a given slew angle, [Model B]
L2min	= The minimum length of L2 needed to still be able to form the side slope
L2X	= Variable used in the calculation of SLa'' and SLb''
LB	= Length of the BWE load boom from the load boom pivot point to the digging wheel centre
LBW	= Distance from a line connecting the load boom pivot point and the digging wheel centre, to the lowest point on the load boom structure

LB'max	= Maximum reach of the load boom and the digging wheel at the maximum given slew angle
LB''min	= Mimimum required distance between the BWE centreline of advance and the side slope toe (defined by digging head design)
R	= Radius of the digging wheel, measured to the bucket cuting lips
R1/R2/R3	= Intermediate values of the digging wheel radius used to determine the distance from the digging wheel centre to the side slope crest in a dropping cut
RB	= Length of the load boom from the load boom pivot point to the digging wheel centre, projected onto the base plane, (with digging wheel buckets at ground level)
RD	= Actual distance from the digging wheel centre to the actual side slope for the dropping cut
SL	= Defined as the slew angle at SLa'', or SLb''
SLa'	= Minimum slew angle used to determine the lower intermediate limit of the side slope angle range, [Models A and B]
SLa''	= Lower intermediate slew angle limit of the side slope angle range, [Models A and B]
SLb'	= Maximum slew angle used to determine the upper intermediate limit of the side slope angle range, [Models A and B]

SLb''	= Upper intermediate slew angle limit of the side slope angle range, [Models A and B]
Wb	= Total cut width measured at the bottom of the cut
Wb'	= Cut width on the slope side of the BWE centreline of advance, measured at the bottom of the cut
Wb''	= Cut width on the pit side of the BWE centreline of advance, measured at the bottom of the cut
Wt	= Total width of cut measured at the top of the cut
Wt'	= Cut width on the slope side of the BWE centreline of advance, measured at the top of the cut
Wt''	= Cut width on the pit side of the BWE centreline of advance, measured at the top of the cut
X1	= The distance the load boom pivot point must move in order to form the front slope angle
X2/X3	= Correction distances required to determine the distance X1
X4	= The horizontal distance of the actual front slope angle projected onto the base plane the excavator crawlers rest on
X5	= Distance projected onto the BWE centreline of advance resulting from using a maximum given slew angle on the slope side of less than 90 degrees

XB/XB'/YB/YB'	= Variables used to calculate the location of the mininum and maximum points of the side slope toe in a dropping cut, [Models A and B]
XB/XYA/XYB/YB	= Variables used in the determination of the minimum and maximum side slope angle in Model C
Y	= Elevation of the load boom pivot point above the crawler level
Y1	= Minimum distance between the BWE centreline of advance, and the side slope toe
Z1/Z2	= Intermediate values used in the determination of F
α	= Side slope angle
αc	= Critical side slope angle (also defined as the vertical wheel free angle)
αmax	= Maximum side slope angle
$\alpha max1$	= Lower intermediate limit of the side slope angle range, [Models A and B]
$\alpha max2$	= Maximum limit of the side slope angle range, [Models A and B]
αmin	= Minimum side slope angle
$\alpha min1$	= Minimum limit of the side slope angle range, [Models A and B]
$\alpha min2$	= Upper intermediate limit of the side slope angle range, [Models A and B]

αo	=	Side slope angle at the offset angle
$\alpha\theta$	=	Side slope angle at offset angle θ
β	=	Front slope angle
β min	=	Minimum value of the front slope angle
θ	=	Offset angle measured on the base plane between L1 and L2
δ	=	Wheel free angle measured in the horizontal plane, (looking in direction of BWE advance)
ε	=	Maximum swing angle of the discharge boom from the centreline of advance, (looking in the direction of BWE advance)
Kd	=	Angle of load boom inclination, from the load boom pivot point to the centre of the digging wheel with the bucket lips at resting on the ground
Kh	=	Angle of load boom inclination, from the load boom povot point to the centre of the digging wheel with the bucket lips above ground level
Khab	=	Load boom incliniation with the buckets at a height of ab above ground level, [Model C]
σ	=	Wheel free angle measured in the vertical plane, (looking in direction of BWE advance)
χ	=	Minimum permitted angle between the load and discharge booms
φ	=	Calculated slew angle

ψ_{L1ab} = Slew angle measuered to a point of (Y1 + L1ab) from the BWE centreline of advance, [Model C]

ψ_{min} = Minimum slew angle on the slope side of the BWE, (a function of excavator design)

ψ_{ms} = Minimum value of the maximum slew angle on the slope side of the BWE centreline of advance, (limited by excavator design, and side slope angle)

ψ_{o} = Slew angle at the bottom of the slope measured to a distance of CW from the BWE centreline of advance, (offset slew angle)

ψ_{p} = Maximum slew angle on the pit side of the BWE centreline of advance measured at the bottom of the cut

ψ_{s} = Maximum slew angle on the slope side of the BWE centreline of advance measured at the top of the slope

1.0 Summary of Results and Conclusions

The Bucket Wheel Excavator (BWE) is a very specialized machine. Detailed mine planning is required in order to get the most from the investment made in it. Mine planning can be more easily accomplished if a set of relationships describing the excavator's limits of application are available. In addition to this, such a set of relationships can aid in the selection of an excavator which is best suited to a particular operation. The objective of this investigation, is to develop and test a series of relationships describing the limitations and applications of a BWE forming either a terrace cut, or a dropping cut.

The objectives were accomplished by developing mathematical expressions which define the interdependence between the BWE's design parameters and the mining face. These expressions can be separated into three distinct relationships which define the following, given specific BWE design parameters:

1/ The minimum front slope angle, and maximum advance

2/ The range of side slope angles

3/ The width of a cut

A series of computer programs have been developed to aid in the computation of these relationships. In turn, these results, (and thus the relationships), were tested by using a scaled-down model of a typical compact (standard) BWE.

The results obtained through this study are:

1/ The relationships developed to describe the limitations of the terrace cut are accurate, and are supported by results obtained using physical model studies

2/ The relationships developed to describe the front face, and the cut width limitations, for the dropping cut can be used with confidence, and are supported by results from physical model studies

3/ Relationship Model C, (Section 4.3.3), describing the side slope angle limitations for a dropping cut, best describes the actual side slope and, has been confirmed using slope model studies

4/ The computer models based on these relationships are accurate, and clearly show the limits of application for any excavator's specific design parameters

5/ Output obtained from the computer models is easy to use, and can be applied to slope design work, or in the selection of an excavator which is best suited to a specific operation

2.0 Introduction to Bucket Wheel Excavators

2.1 BWE Development

The first patent for a continuous earth moving bucket wheel was granted in 1881. It was not until 1916 however, that the first BWE designed for mining overburden was constructed. This first attempt was a failure, but by 1925 a successful machine had been developed (Rasper, 1975). With the technology available today, BWEs capable of moving over 200,000 cubic meters of material per day have been constructed.

During the development of the BWE, several design changes occurred over time. The most significant are:

1/ Rails replaced by crawlers
2/ Crowd-boom replaced by crowd-less boom
3/ Cell-type wheel replaced by cell-less wheel
4/ Deep/high digging replaced by high digging only

Although BWEs are built to meet the specific needs of the operator, the majority of the excavators constructed today reflect these changes.

Rails were used on early machines because at the time, this was the most efficient way of moving such large pieces of equipment. These original rail travel systems caused operational difficulties and as crawler technology advanced, rail systems were replaced in favor of crawler systems, (Aiken, 1968, Durst, 1982).

Rail systems still have a place where conditions are suitable, for example Bucket Chain Excavators (Aiken, 1968). In terms of excavator cost and travel gear reliability, rail systems retain important advantages.

In addition to rail and crawler travel systems, walking mechanisms can be used. These have found limited application (Kharakhash, 1967), but are not likely to become widely used (Rasper, 1975).

The limited flexibility of rail mounted BWEs called for the employment of a crowd boom as a means of increasing excavator flexibility. This flexibility not only allowed the excavator to make the required advances, but also allowed the operator to control the depth of the slice in order to maintain a constant chip volume. (see figure 2.1). The use of a crowd boom can increase machine weight from 10 to 35 percent over excavators without crowd action, and also adds additional mechanical and maintenance problems (Martin, 1982). Because of this, the crowd boom is seldom justified economically on todays excavators (Aiken, 1966, 1968, 1973).

One problem encountered with the elimination of the crowd action, is the formation of a sickle shaped cut. (figure 2.2). At constant slewing speeds, the chip volume excavated by each bucket decreases, because the slice

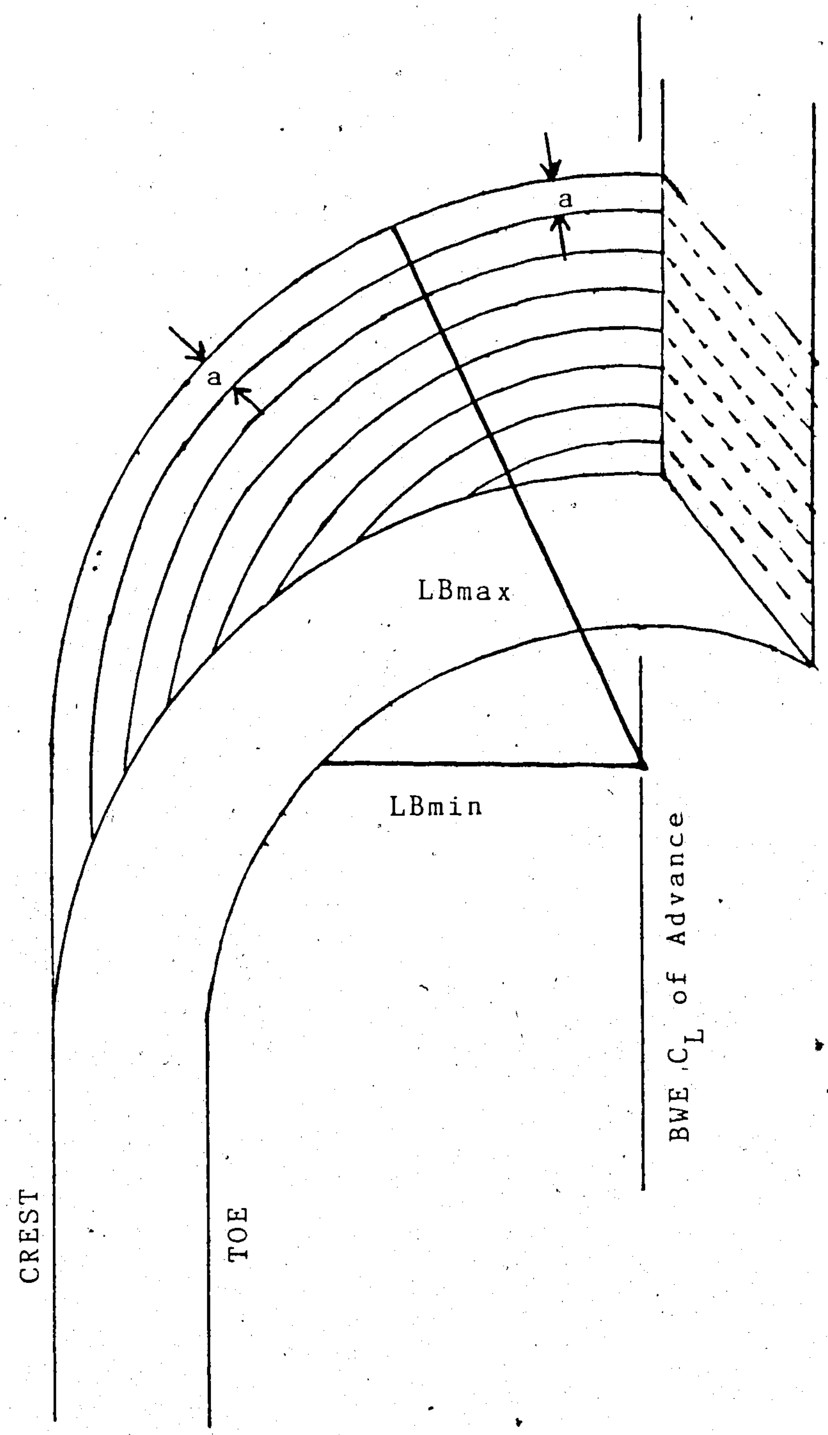


FIGURE 2.1 Formation of a cut using a crowd-type load boom

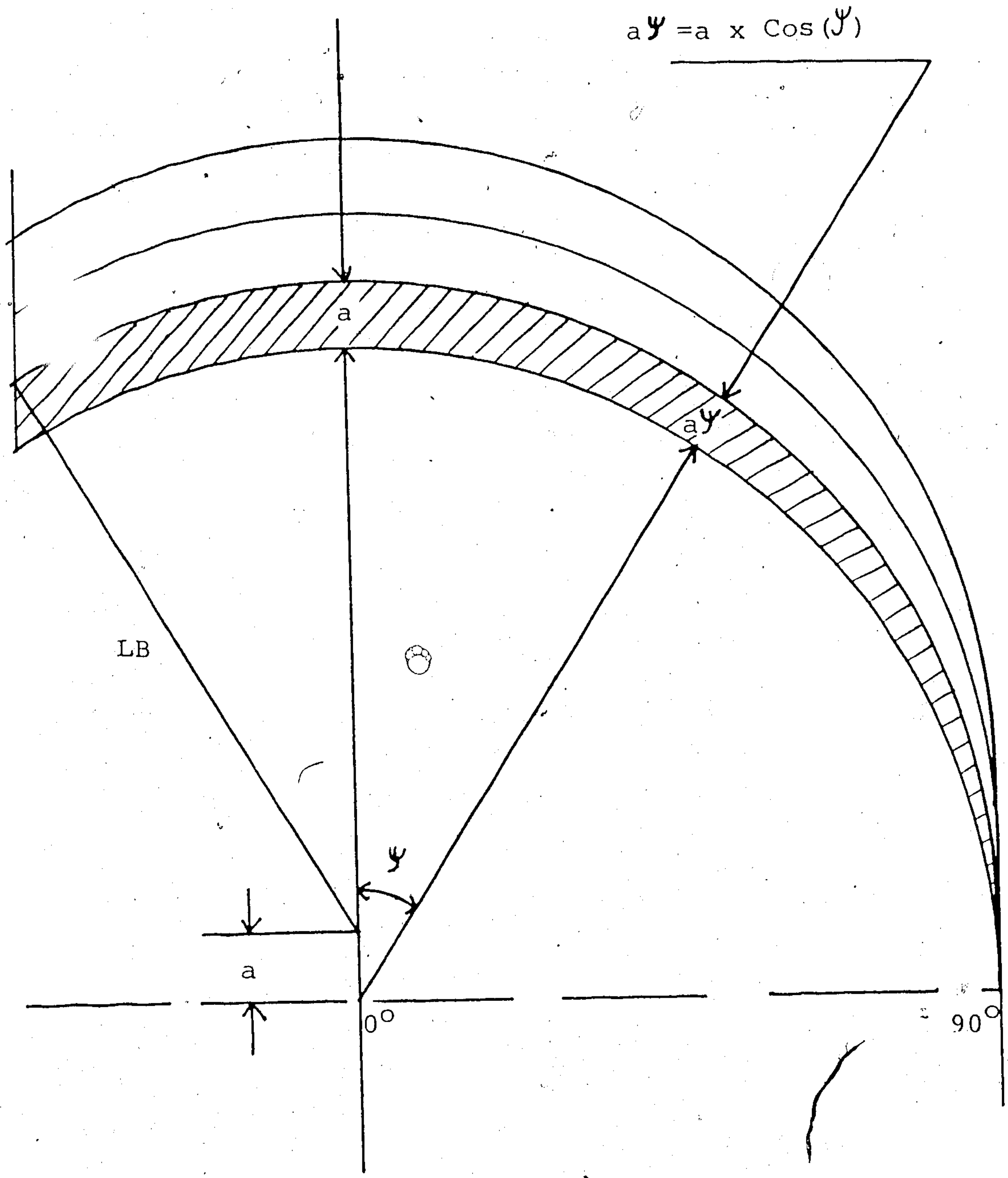


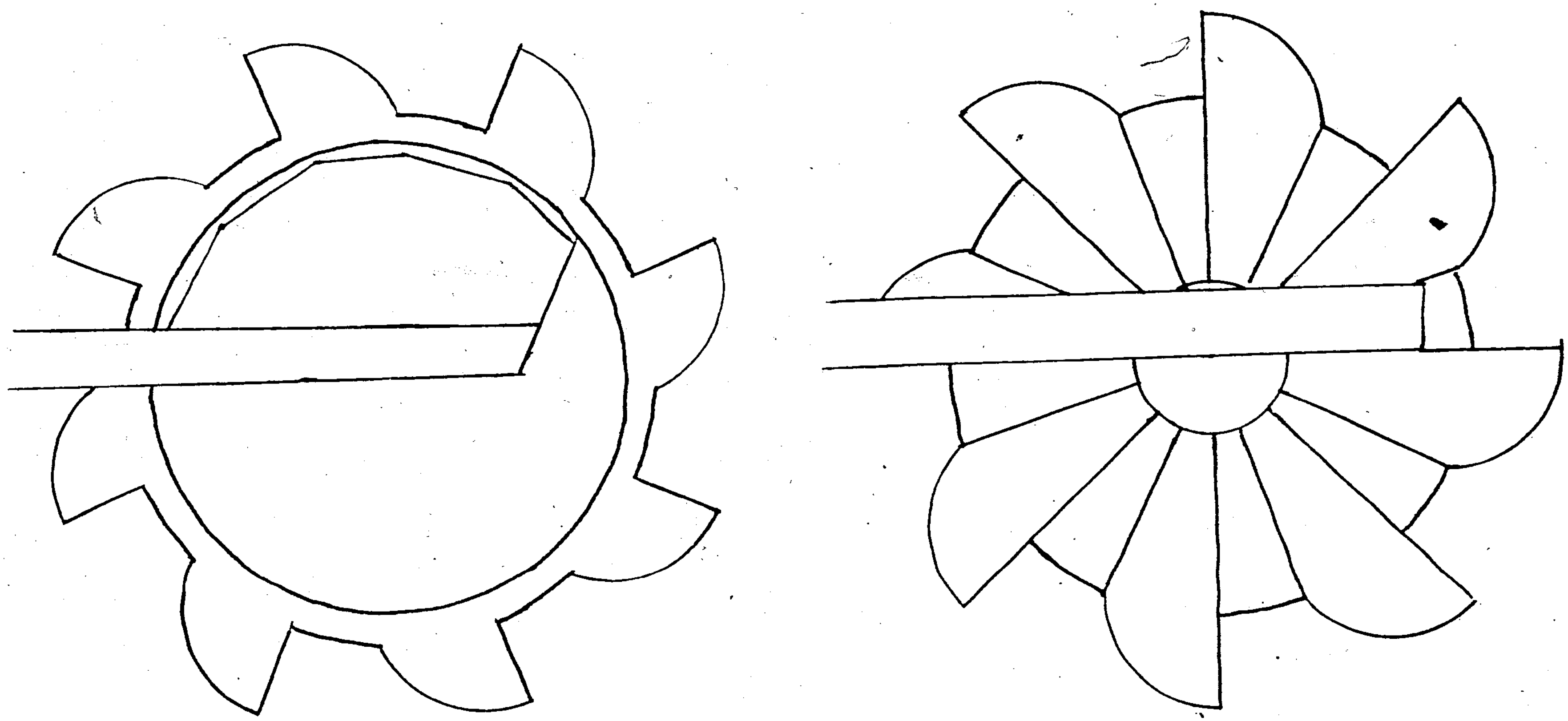
FIGURE 2.2 Sickle shaped cut formed by a BWE with a crowd-less boom. To compensate for reduced chip volume, the slew speed is increased as the slew angle increases.

thickness decreases as the slew angle increases. This problem can be minimized by increasing the slew speed as a function of the slew angle to keep the chip volume constant.

Early machine designs incorporated the cell type bucket wheel, but these are being replaced in favor of the cell-less wheel (Krumrey, 1979), (see figure 2.3). The cell-less wheel allows much greater wheel speeds to be used, because the bucket emptying characteristics are better. This increase in wheel speed provides greater discharge capacities compared to a similar excavator with cell type buckets.

Another advantage of the cell-less wheel is found in deep cutting. With a cell type wheel, the buckets cannot be reversed; therefore, a longer load boom must be used. This adds to the excavator weight and cost (Krumrey, 1979).

A BWE works in high cut when excavating above crawler level and in deep cut while excavating below crawler level. Originally, machines were designed to take advantage of both types of cuts. In recent years, the trend has been away from the deep cut, because of the time required to reverse buckets, (increased downtime), and the need for a cover conveyor on the load boom when conveyor angles exceed -22 degrees, (figure 2.4) (Aiken, 1968).



Cell-less digging wheel

Celled digging wheel

FIGURE 2.3

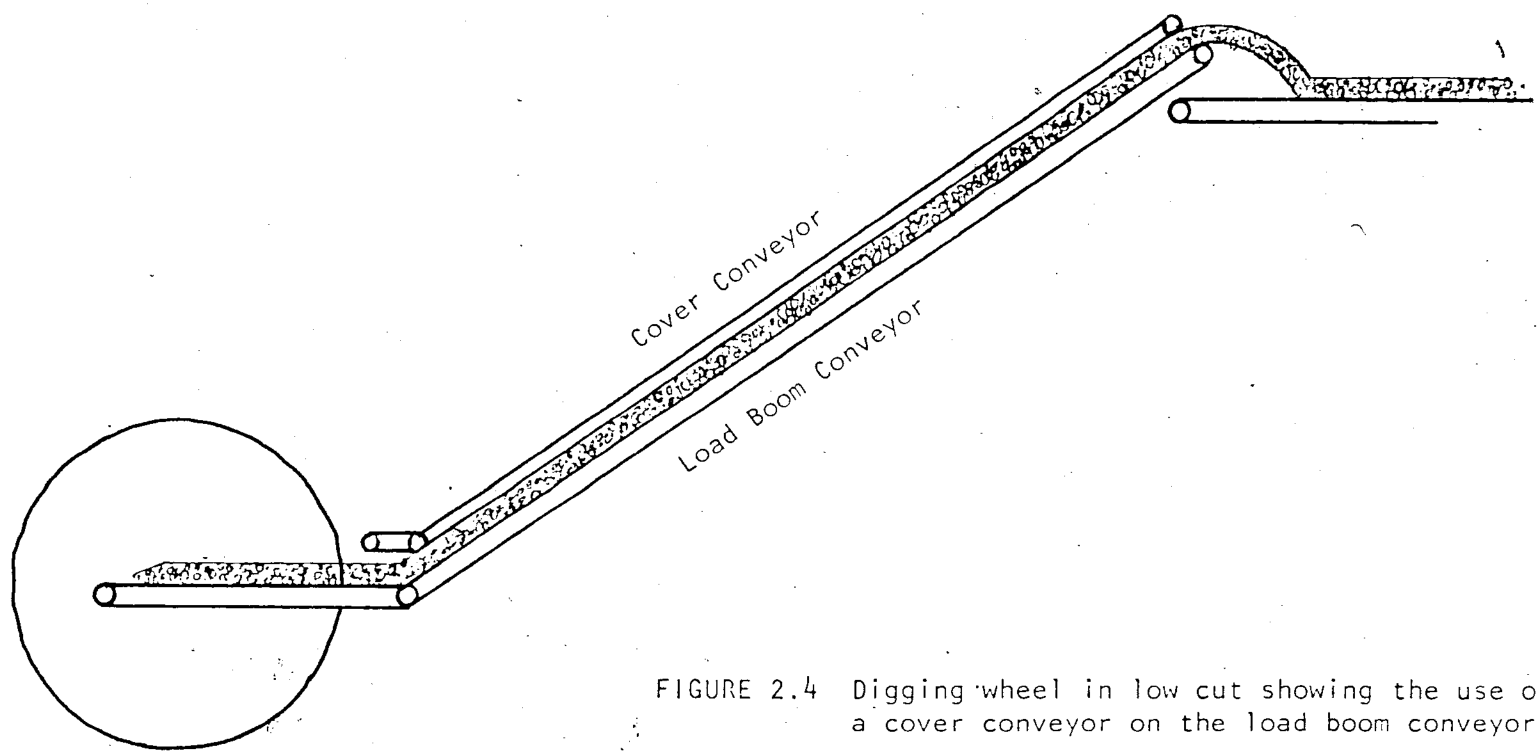


FIGURE 2.4 Digging wheel in low cut showing the use of a cover conveyor on the load boom conveyor

2.2 BWE Applications and Limitations

To determine if a BWE is suitable for mining a deposit, several details must be investigated. The most important consideration in BWE selection is the type of material to be excavated. Compared to other excavators such as shovels and draglines, the BWE has relatively small digging forces (Rasper, 1975). To avoid costly misapplication, extensive material testing is required to determine its diggability.

Once it has been determined that a BWE is capable of excavating a deposit, a careful study must be made of the deposit characteristics. Factors like deposit depth, shape, and floor inclination must be considered (Aiken, 1966). These factors influence support equipment requirements, and the need for special bench designs.

Other characteristics which influence an excavator's ability to mine a deposit are material variability, and the presence of water and boulders. These can have a significant impact on the choice of an excavator.

Once it has been determined that a BWE operation is feasible in a given deposit, consideration must be given to the design of the excavator slope. There is a direct relationship between the BWE design parameters and slope formation. This fact makes the BWE less flexible in its application than other mining units, and underlines the need for proper planning and attention to detail in order to minimize potential problems, and to maximize output (Aiken, 1968, 1973).

Recent advances in design have moved the BWE into materials which were previously the domain of shovels and draglines. With improved blast engineering and explosives, even harder materials may become minable by BWEs (Aiken, 1968).

In addition to the wide range of materials BWEs handle, they can be employed under a wide range of temperature, rainfall and wind conditions. BWEs have been used in West Pakistan for canal construction, where daily temperatures up to 55 degrees Celsius were encountered. They are also used in Canada and the Soviet Union where temperatures of -40 degrees Celsius or lower are not uncommon (Rasper, 1975).

The range of application for the BWE can be expanded by using them with other mining equipment. The best example of this combined application is at United Electrics Fidelity mine (USA), where a BWE is working in tandem with a large stripping shovel (Roman, 1968). This combination is very successful, and opens up a wide range of possibilities. BWEs also find wide acceptance in areas where selective mining is required.

The BWE's ability to handle a wide range of material under a variety of conditions, make them suitable for use all over the world. This, in addition to its special design features, such as continuous excavation and selective mining, can make them economically justifiable in many deposits now considered by many to be suitable only for shovel or dragline excavation.

2.3 Mining Face Terminology

To understand the relationships between a BWE and the mining face, one must understand the face terminology. Figures 2.5a, 2.5b and 2.5c illustrate the following terms:

Crawler level	The plane at the base of the BWE crawlers.
Block	The strip of material removed by the excavator on each advance in the direction of mine advance.
Block Height (Blh)	The total height of material that is removed by the excavator on each advance in the direction of mining; includes high cutting and deep cutting.
Block Width (Blw)	The width of the excavation removed by the excavator on each advance in the direction of mining.
Block Length (Bll)	The total length of the block removed on each advance in the direction of mining.
Bench	The part of the block the excavator can work at any one time; measured above crawler level, or below crawler level.

Bench Height (Bh)	The height of the excavation measured above or below crawler level.
Bench Width (Bw)	Same as block width (Blw).
Face	The front plane of a bench facing the direction of the BWE advance (Bh x Bw).
Advance (A)	The distance the excavator moves into the face on each cut (limited by BWE design).
Cut	The volume removed by the excavator on each advance (Bh x Bw x A).
Terrace	The part of the cut removed by the digging wheel on each advance into the face.
Slice	The part of the terrace removed during one swing of the excavator.
Slope	The plane connecting the floor and the top of the bench which best represents the face.
Toe	The edge where the slope meets the bench floor.
Crest	The edge where the slope meets the top of the bench.
Pit Side	The side of the BWE on which the old side slope is located.
Slope Side	The side of the BWE on which the new side slope is located.

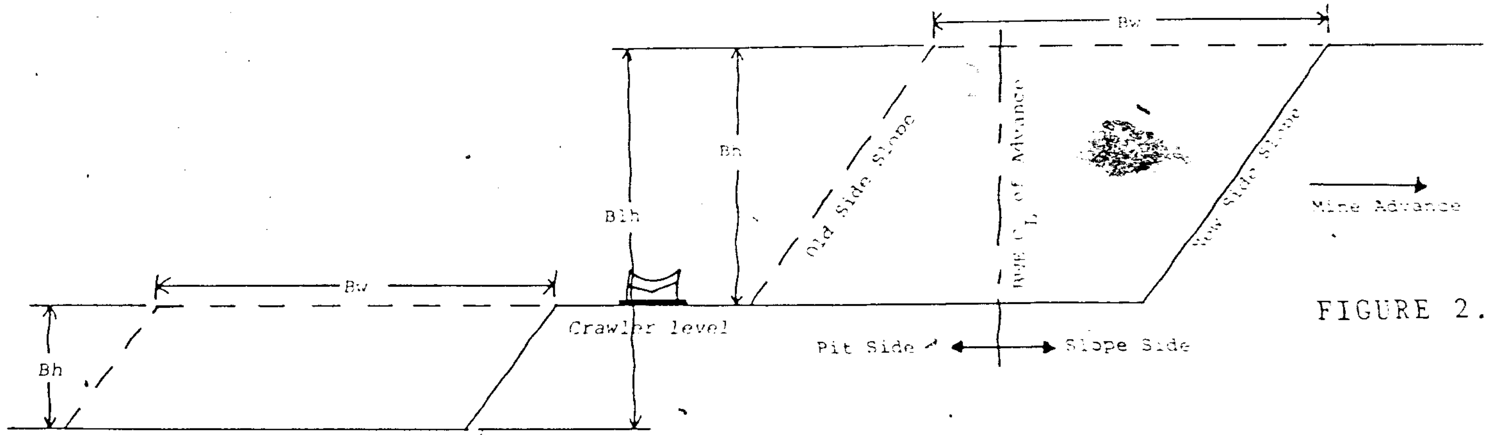


FIGURE 2.5a

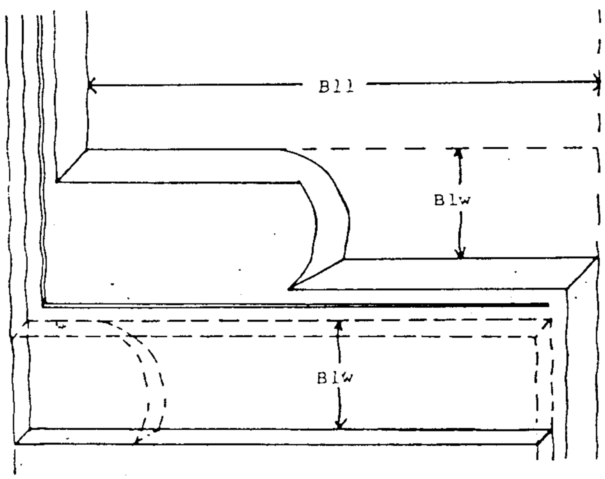


FIGURE 2.5b

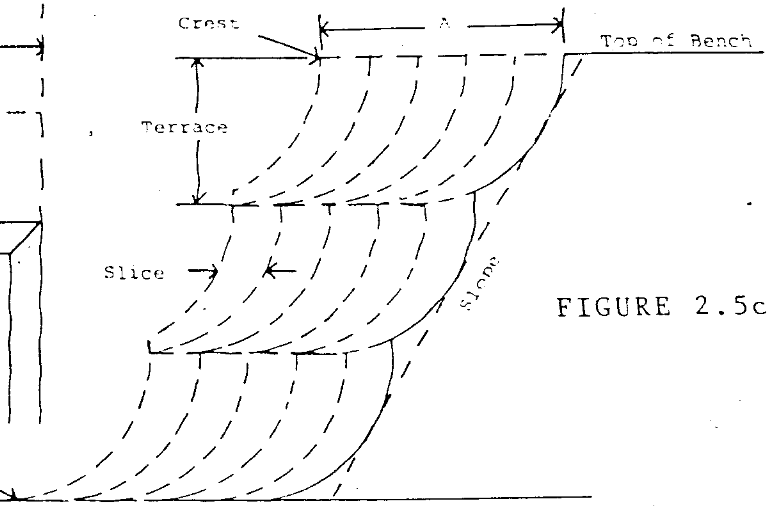


FIGURE 2.5c

MINING FACE TERMINOLOGY

This terminology is used throughout this report.

2.4 Cut Types

The BWE can be used in three types of cuts:

1/ Terrace cut,

2/ Dropping cut, and

3/ Combination cut.

Selection of the type of cut depends mainly on the type of material being excavated. Each type of cut has its advantages and disadvantages, and field tests should be conducted before cut selection is made (Singhal, 1983).

A terrace cut is formed by positioning the digging wheel at the top of a mining slope such that the terrace excavated is between 0.5 and 0.7 times the digging wheel diameter (Martin, 1982). The wheel is then advanced into the face by a distance equal to the depth of the buckets and a slice is removed from the terrace. When this slice is extracted, the wheel is advanced by the depth of the buckets for the next slice. This procedure continues until the load boom is about to touch the crest of the second terrace, or until the crawler is about to strike the front slope toe. The excavator is retreated, the wheel boom lowered to the next terrace, and the process repeated, (see figure 2.6). Once the entire cut has been removed, the excavator load boom is raised and positioned for the next cut.

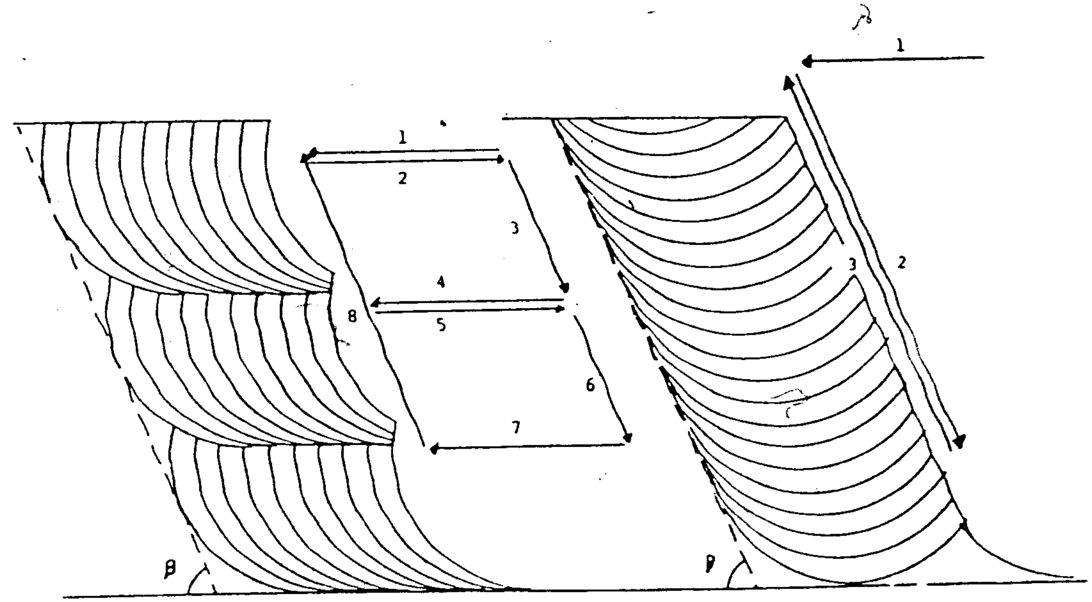


FIGURE 2.6 Terrace and dropping cut showing the excavator movements required.

The dropping cut is formed by positioning the digging wheel to extract a cut of 0.5 to 0.7 times the digging wheel diameter. The load boom is then lowered by a distance equal to the depth of the buckets and the wheel slewed to remove a slice from the cut. The load boom is again lowered by the depth of the buckets and the excavator retreated to form the required front slope angle, and the next slice is removed. This process continues until the whole cut is extracted, (see figure 2.6). The excavator is then repositioned for the next cut.

The combination cut is used in situations where the bench height is too large to employ only the dropping cut, (bench height is above maximum selective digging height), or to reduce the total excavator movement in a terrace cut, (see figure 2.7) (Hoffmann, 1983).

The terrace cut offers the advantage of simple slope design as compared to the dropping cut. The slew angle remains constant on each terrace, thus it lends itself readily to automation of the cutting sequence. One disadvantage of the terrace cut is the total excavator movement required, is much greater than for the dropping cut, (see figure 2.6) Also, if the material is semicompacted, frozen,or has had layers, the terrace cut can produce large lumps which may plug transfer points and increase downtime (Aiken, 1968).

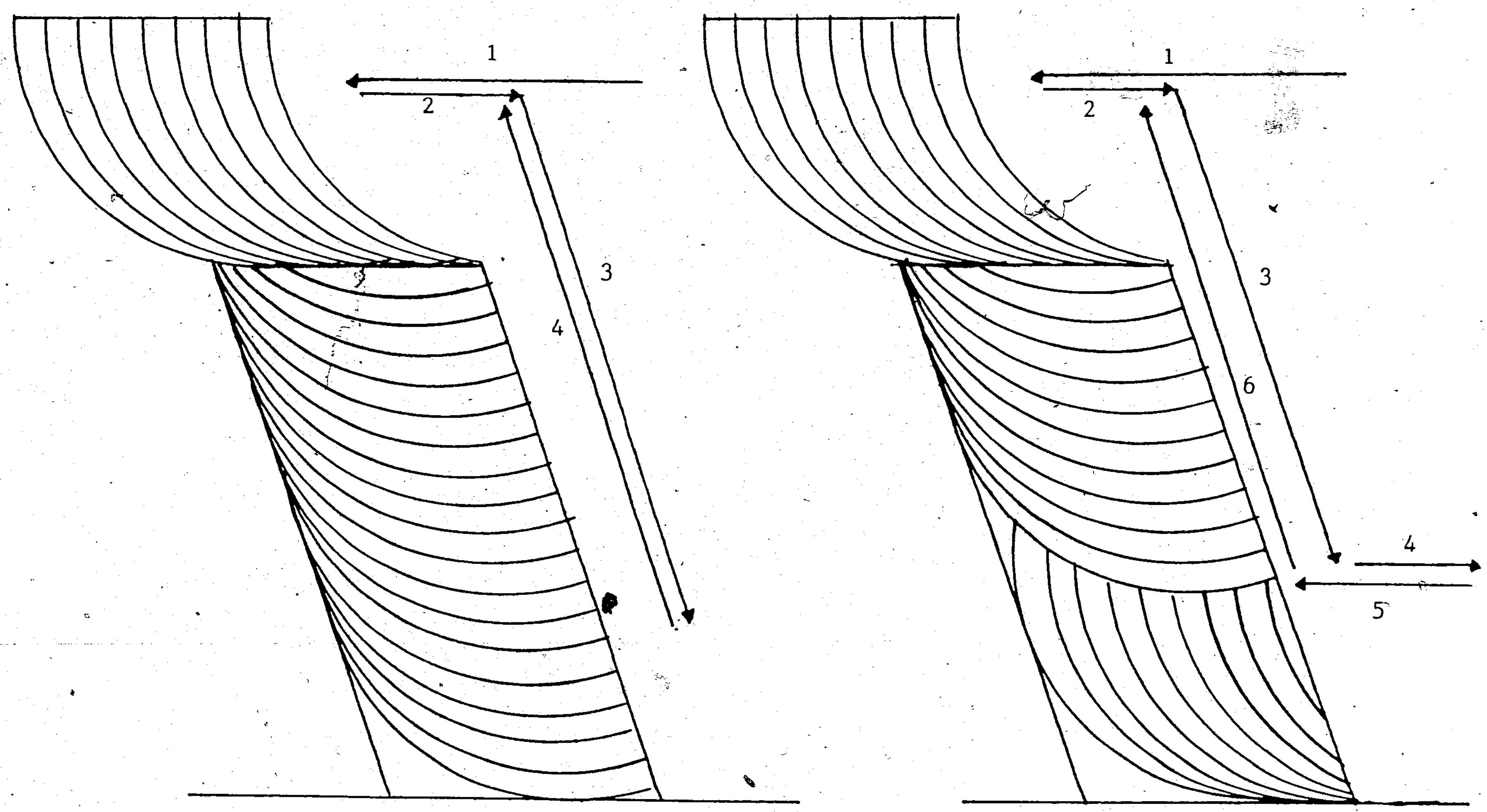


FIGURE 2.7 Combination cuts showing excavator movements required

The dropping cut is employed when the material being excavated is blocky, or when the horizontal direction of the cutting force aids in excavation. The advantage of the dropping cut is that it gives better lump control in frozen or semiconsolidated material than the terrace cut. The main disadvantage of the dropping cut occurs in the formation of the side slope. To form the side slope, the slew angle must be reduced on each slice the wheel makes down the face. This makes it more difficult to automate the cutting sequence (Hoffmann, 1983).

Cut productivity for both the terrace cut and the dropping cut is essentially the same. When power consumption is considered, the dropping cut uses more power than the terrace cut, unless the material being excavated has a horizontal bedding plane (Martin, 1982).

2.5 Potential for BWE Application in Western Canada

The only full scale BWE operation in North America is in the Athabasca oilsands region of northern Alberta. Of the two existing operations, one is dedicated fully to BWEs, while the other uses BWEs as reclaimers. Because of the vastness of the deposits, (estimated at some 25 billion cubic meters of oil recoverable using mining techniques), further development is assured: and the BWE will play a major role in the recovery of this resource.

The application of BWEs to the oilsand region illustrates several requirements for the successful implementation of a BWE system. These requirements are:

1/ Large volumes of material to be mined,

2/ A reasonably thick, and geometrically regular deposit, and

3/ Material characteristics amenable to BWE excavation.

If these conditions are meet, BWEs may be applied to the deposit. However, there are other disadvantages and advantages which must be considered before a final decision is made.

The application of BWEs in other areas of North America has been investigated over many years. BWEs proved their usefulness in the coal fields of Illinois, and in overburden removal in Washington. Marston, (1976), did an investigation of the coal fields of the western United States, to classify the areas where there is potential to use BWEs. He concluded that there is potential to employ BWEs in Wyoming, Colorado, Montana, and possibly in Arizona and New Mexico. In addition to Marstons' study, Benecke, (1979), also demonstrated the application of BWEs to the Texas lignite deposits. At present, one operation is being brought on stream and an additional one is in the planning stages.

If a similar study were conducted in Western Canada, the plains coal regions of central Alberta, and the lignite producing region of Southern Saskatchewan, would be prime candidates for BWE application (Krzanowski, 1984). These two areas have relatively soft overburdens and regular coal seams.

Another potential use of BWEs, not related to mining, is in the construction of earth dams, as proposed in Southern Alberta. They also can be considered for road construction, and for water diversion projects which may take place in the future.

3.0 Objectives of Thesis

The objectives of this thesis are to:

1/ Determine which relationships are required to relate the BWE design parameters to the face geometry limits for both the terracing and dropping cuts

2/ Develop analytical models which permit easy quantitative definition of the above relationships

3/ Develop computer programs to simplify the calculations of the above models

4/ Verify the relationships and analytical models by studies using a scaled-down replica of a typical BWE

By accomplishing these objectives, this thesis provides a mine engineer with the information required to:

1/ Investigate the applicability of a particular BWE to a given set of geotechnical conditions

2/ Plan mining faces for a particular BWE

3/ Choose the BWE best suited to a particular mining face design

4.0 Development of Relationships

Presented in this chapter are the definitions of the BWE and slope design parameters which influence the mining face limits, (Hillesheim, 1979). Additionally, the author develops the relationships between the face design limits and the BWE design parameters, for both the terrace and dropping cuts. These relationships are determinable through the use of geometry.

All relationships in this chapter are determined using a bench above the crawler level, (see section 2.3).

4.1 Bucket Wheel Excavator and Slope Design Parameters

Before any development of relationships can be considered, the design parameters of the excavator and slope must be defined. They form the basis of the relationship development, and detailed definitions are needed to avoid confusion. The following symbols are used throughout this thesis; additional symbols are defined in the text as required. For a full list of symbols, refer to Appendix I.

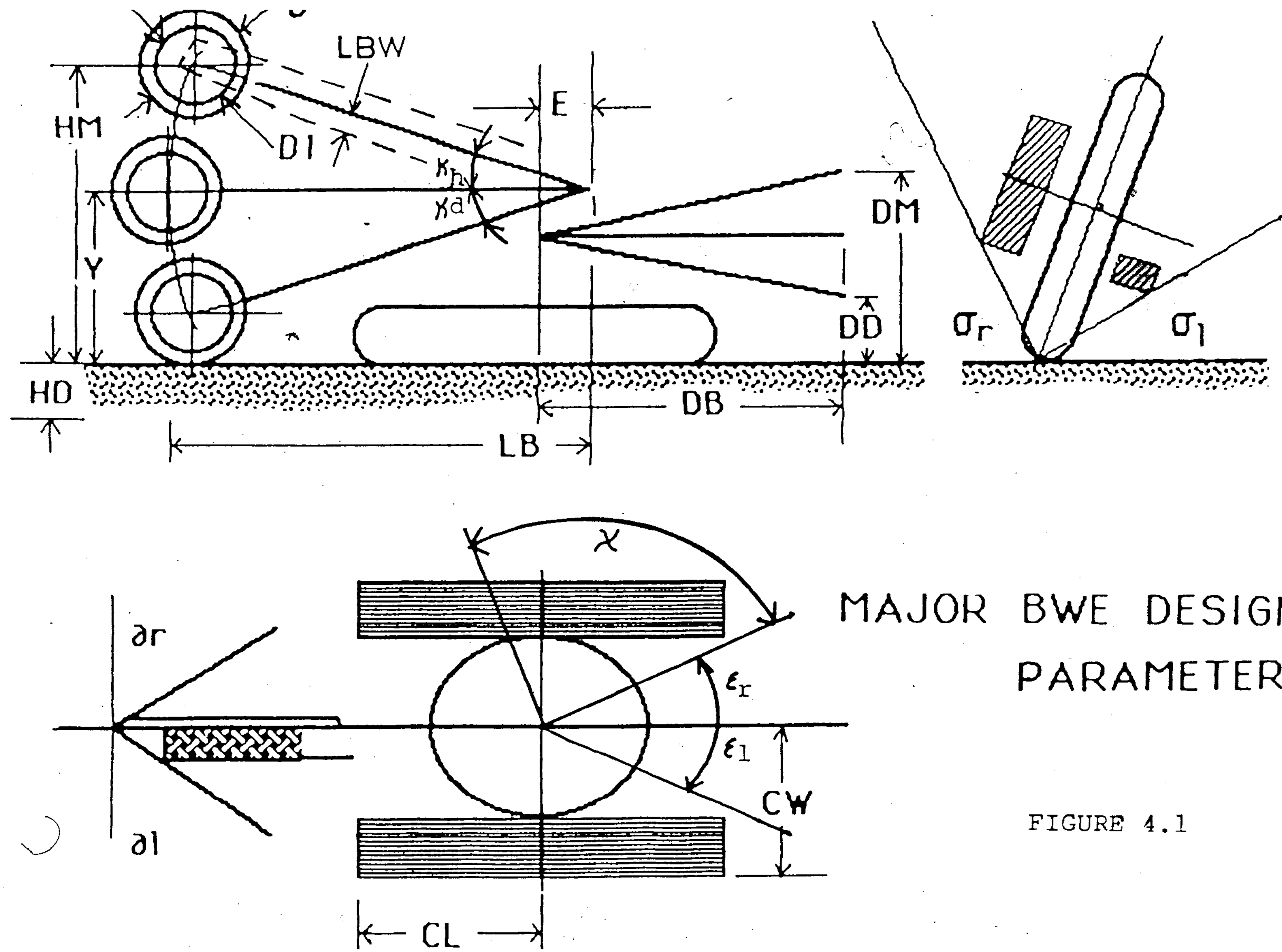
4.1.1 *The Bucket Wheel Excavator (BWE)*

Figure 4.1 shows a representation of a typical compact BWE and is used to aid in parameter definition. The major design parameters are:

CL	Distance between leading edge of the crawler and the centre of rotation of the BWE
CW	Distance between the outside edge of a crawler and the BWE centreline of advance
D	Digging wheel diameter, measured to the bucket cutting lips
D1	Digging wheel diameter without buckets, at wheel rim
DB	Length of BWE discharge boom between the discharge boom pivot point and the material discharge point
DD	Mininum elevation of the discharge chute above crawler level, measured at discharge end of the discharge boom
DM	Maximum elevation of the discharge chute above crawler level, measured at discharge end of the discharge boom
E	Distance between the load boom pivot point and centre of rotation of a BWE; can be positive or negative (E is positive when the load boom pivot point is located on the discharge side of the centre of rotation).
HD	Maximum depth the excavator can work below crawler level

HM	Maximum elevation of digging wheel centre above working level (above crawler level)
LB	Length of BWE load boom from the load boom pivot point to the digging wheel centre
LBW	Width of the load boom from a line connecting the load boom pivot point and the digging wheel centre, and the lowest point on the load boom structure
Y	Elevation of load boom pivot point above crawler level
Kd	Angle of load boom inclination from a line at the elevation of the load boom pivot point to the centre of the digging wheel, with bucket lips resting on the ground
Kh	Angle of load boom inclination from a line at the elevation of the load boom pivot point to the centre of the digging wheel, with bucket lips above ground level
δ_1	Wheel free angle measured in the horizontal plane, left side (looking in the direction of BWE advance)

δ_r	Wheel free angle measured in the horizontal plane, right side (looking in the direction of BWE advance)
σ_l	Wheel free angle measured in vertical plane, left side (looking in the direction of BWE advance)
σ_r	Wheel free angle measured in vertical plane, right side (looking in the direction of BWE advance)
ε_l	Maximum swing angle of the discharge boom from the centreline of advance, left side (looking in the direction of BWE advance)
ε_r	Maximum swing angle of the discharge boom from the centreline of advance, right side (looking in the directiion of BWE advance)
$\varkappa$	Minimum permitted angle between load and discharge booms



LBW
HM
DI
E
Y
HD
LB
DB
DM
DD
σr
σl
∂r
∂l
CW
CL
εr
εl
MAJOR BWE DESIGN
PARAMETERS

FIGURE 4.1

1.2 *The Slope*

To effectively define the relationships between the ning face limits and the excavator, a definition of the ope symbols is required to avoid ambiguity. The selected mbols are:

α	Side slope angle
αc	Critical side slope angle (equal to the vertical wheel free angle)
αmax	Maximum side slope angle
αmin	Minimum side slope angle
β	Front slope angle
βmin	Minimum front slope angle

The slope design not only depends on the slope angles sted above, but also on the slew angles the excavator ikes from the centreline of advance. These slew angles e:

ψ	Calculated slew angle
ψmin	Minimum slew angle on slope side of BWE (a function of excavator design)
ψp	Maximum slew angle of bottom cut on the pit side of the BWE
ψs	Maximum slew angle of top cut on the slope side of the BWE

4.1.3 *Definition of the Wheel Free Angles*

The BWE horizontal and vertical free angles influence the BWE's ability to form slopes in both terrace and dropping cuts; therefore, their definition is important in order to obtain the proper face limits.

Three definitions for the wheel free angles can be used:

1/ Definition used in this study

2/ Definition used by the State Electrity Commission of Victoria, (SECV)

3/ Actual angle as experienced in an operation

The actual angle is measured between a line perpendicular to the digging wheel centreline, and a line from the widest point on the digging wheel contour, plus a safety distance (usually 20 cm.), to a point tangent to the outside edge of the buckets, (δactual in figure 4.2 and σacutal in figure 4.3). This method depends on the shape of the buckets, which can vary between excavators; therefore, it is not used. The other two definitions are detailed later in this section.

The Horizontal Wheel Free Angle (HWFA) is used to define the minimum slew angle the BWE must make on the bottom terrace of the excavator's slope side. An angle smaller than this will result in a collision between the bucket wheel digging head and the side slope, (Birkheuer, 1983). This angle is important in the formation of the side slope, and in the construction of box cuts and ramps.

The Vertical Wheel Free Angle (VWFA) is important in determining the mining face limits for a dropping cut. It defines the maximum side slope angle which can be formed. An angle steeper than the VWFA, will result in a collision between the digging head and the side slope, (Rodgers, 1971, 1976).

The definition of the HWFA most often found in literature is that used by the State Electricity Commission of Victoria (SECV) Australia (Rodgers, 1971, 1976; Campbell, 1978). In this definition, the HWFA (measured in the horizontal plane) is taken as the angle between a line perpendicular to the BWE centreline of advance, (line X-X in figure 4.2), and a line connecting the widest point on the digging head contour plus a safety distance, (usually 20 cm), to the digging wheel centre line at the lips of the buckets. The safety distance is added to prevent the digging head from s[illegible]g the side slope. This angle is defined as δSECV in figure 4.2.

A slightly different definition is used in this study. In this definition, the HWFA is the angle between a line perpendicular to the BWE centreline of advance, (Line X-X in figure 4.2), and a line connecting the widest point of the digging head contour, to the digging wheel centre line of the lips of the buckets, (δMEP in figure 4.2). There are two reasons for using this definition:

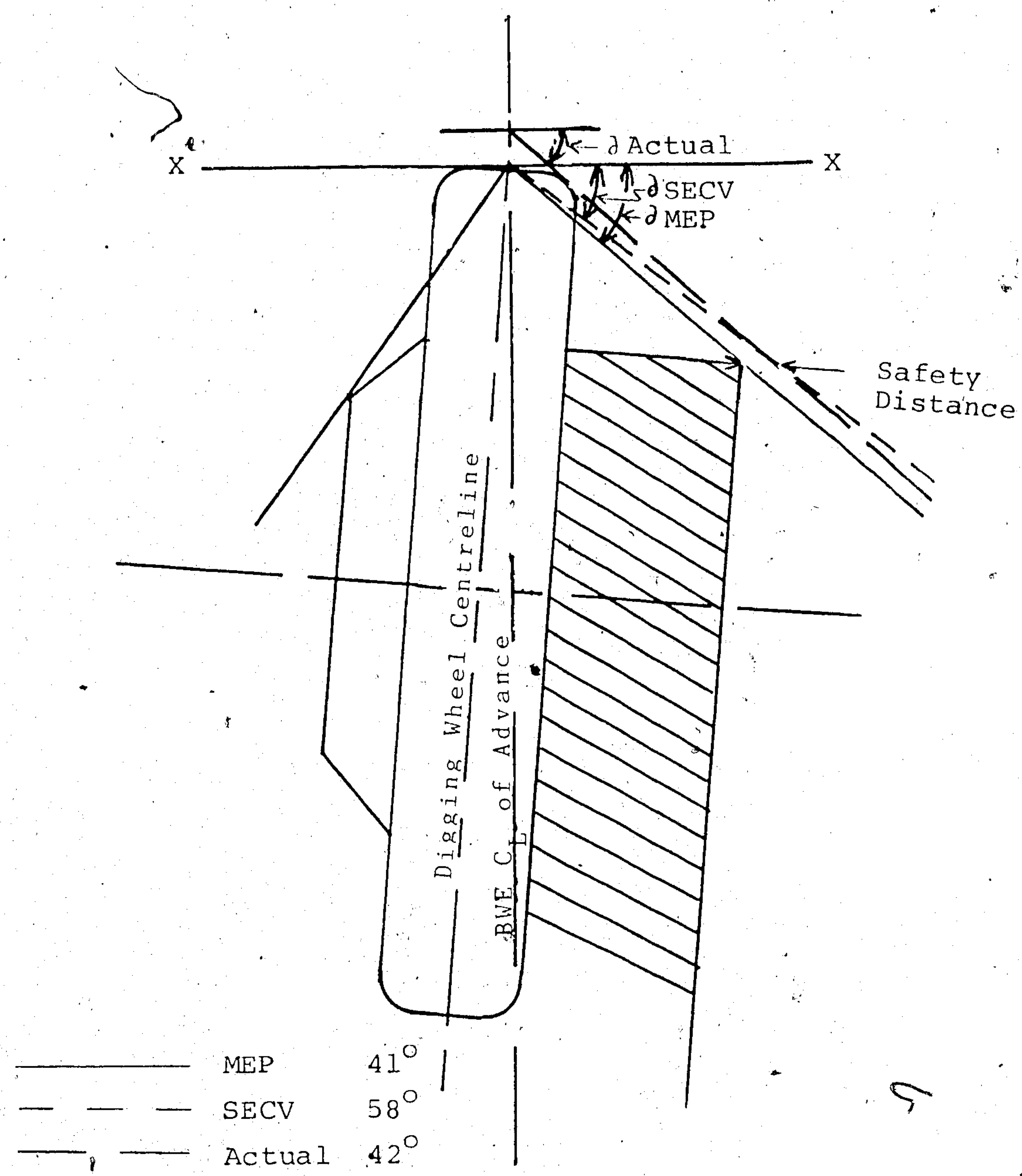
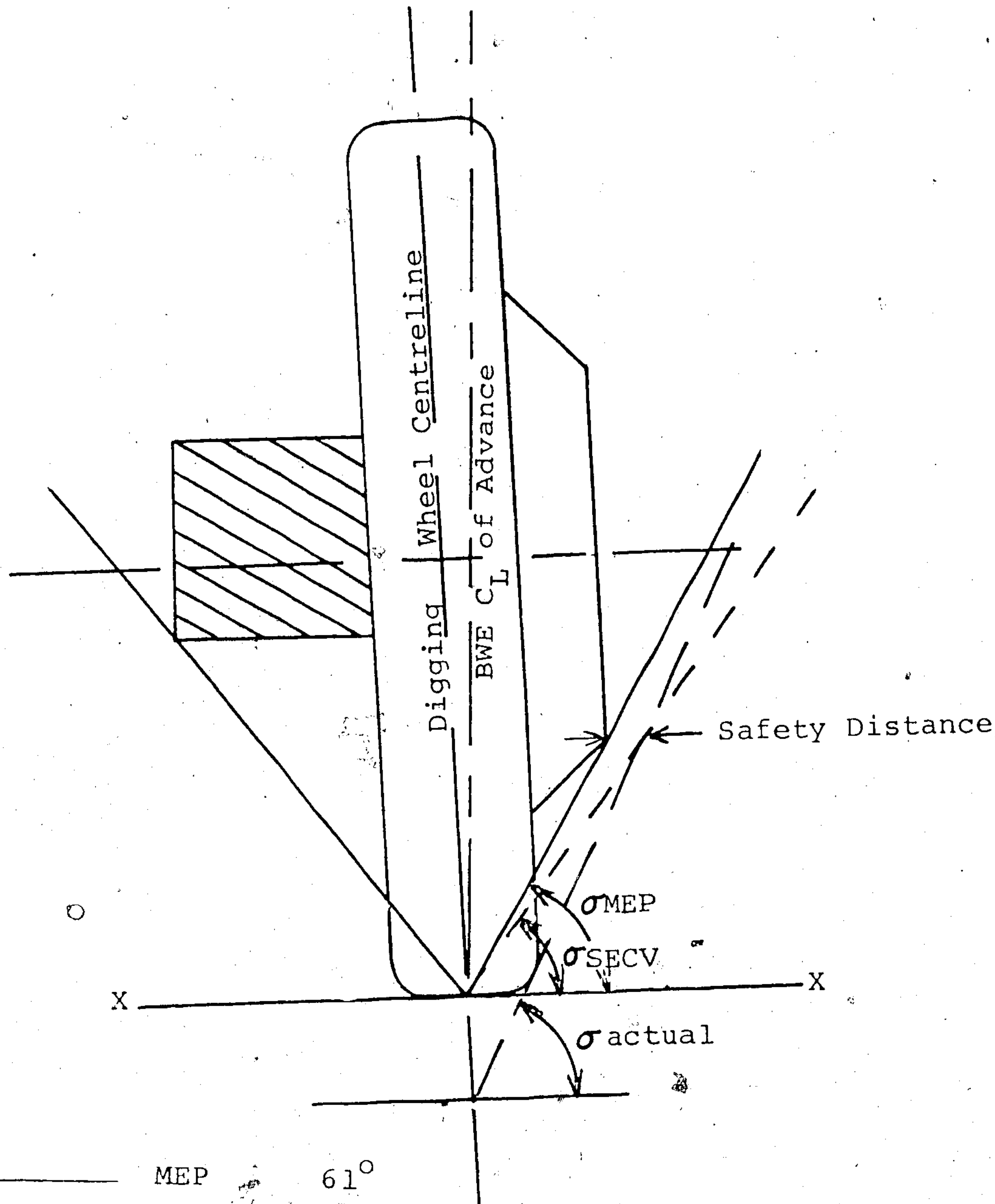


FIGURE 4.2
Horizontal wheel free angles

1/ It can be measured directly from manufacturers drawings without the need to define a safety distance between the digging head and the slope

2/ The angle obtained, while more conservative than the actual angle, (as defined above), is less conservative than that used by SECV for rectangular shaped buckets (which are most used). This makes the predicted limits closer to those which are found under actual mining conditions

The definition of the VWFA is similar to that used for the HWFA, but measured in the vertical plane. The definition found most often in literature is that used by SECV (Rodgers, 1971, 1976; Campbell, 1978). It is defined as the angle between a line perpendicular to the digging wheel centreline, (line X-X in figure 4.3), and a line connecting the widest point on the digging wheel contour plus a safety distance, to the digging wheel centre line at the bucket lips (σSECV in figure 4.3). The definition of the VWFA used in this study is the angle taken from a line perpendicular to the digging wheel centreline, (line X-X in figure 4.3), to a line connecting the widest point on the digging wheel contour to the digging wheel centre line at the buckets lips. The reasons for using this definition are the same as those used for the HWFA.



MEP 61°

SECV 55°

Actual 64°

FIGURE 4.3

Vertical wheel free angles

For both wheel free angles, the difference between the three definitions, (MEP, SECV, Actual), are shown in figures 4.2 and 4.3.

4.2 Terrace Cut

4.2.1 *Introduction*

The ability of a specific BWE to form terrace cut slopes is limited by

1/ Minimum front slope angle as a function of advance and bench height
2/ Maximum permissable advance as a function of front slope angle and bench height
3/ Minimum side slope angle as a function of bench height
4/ Width of cut as a function of side slope angle and bench height

The above limits (taken after Golosinski, 1983) are also important in the design of mining slope for a particular BWE, or in the selection of a BWE capable of forming the required mine slopes (Boehm, 1982). To aid in the quantitative definition of these limits, computer programs are developed in Chapter 5 which incorporate the relationships established in this section.

The calculation of load boom inclination is important in the development of the relationships within this section. If the digging wheel is positioned on the bottom terrace, with the buckets at crawler level, the load boom inclination, (see figure 4.1), is found as:

$$Sin(Kd)=(Y-R)/LB \qquad 4.1a$$

For all other digging wheel locations, the following hold true:

$$Sin(Kh)=(Y-H)/LB \text{ if } H<Y \text{ and } H\geq R \qquad 4.1b$$

$$Sin(Kh)=(H-Y)/LB \text{ if } H\geq Y \text{ and } H<HM \qquad 4.1c$$

$$Sin(Kh)=(HM-Y)/LB \text{ if } H\geq HM \qquad 4.1d$$

where

H	=	Bench height
HM	=	Maximum lift of the digging wheel centre
LB	=	Length of load boom
R	=	Digging wheel radius
Y	=	Elevaton of load boom pivot point

4.2.2 *Front Slope Angle and BWE Advance*

If a BWE is advanced to the same position on all terraces, the resulting slope is approximately 90 degrees.

However, such a steep slope is usually unstable. To form a front slope of less than 90 degrees, the BWE must be advanced to a different position on each terrace. This is shown in figure 4.4. There is a minumum value to which the front slope angle can be reduced; as defined by a BWE's design parameters. It follows that the maximum range of front slope angles which can be formed is:

$$\beta_{min} \leqslant \beta \leqslant 90^{\circ} \tag{4.2}$$

The development of the relationships between the excavator design and the minimum front slope of a mining face is based on analysis of the slope forming process. Figure 4.5 shows the formation of a front slope using a terrace cut.

For a terrace cut, there are two limits on the front face which must not be exceeded. These limits are:

1/ The interference between the excavator crawlers and the slope toe

2/ The interference between the excavator load boom structure and the crest of the second terrace

The interference between the excavator crawler and the slope toe can result in crawler damage; while interference between the load boom and the crest of the second terrace can result in damage to the load boom.

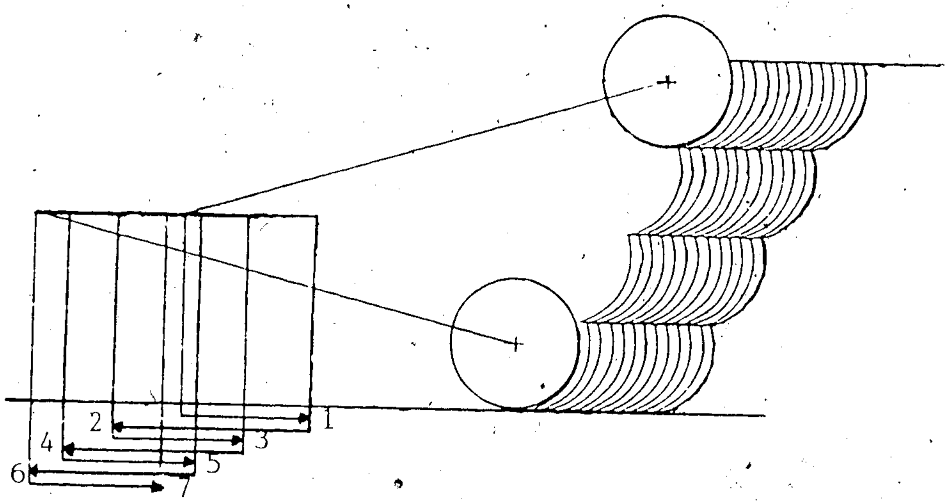


FIGURE 4.4 Formation of a front slope angle by advancing to different positions on each terrace

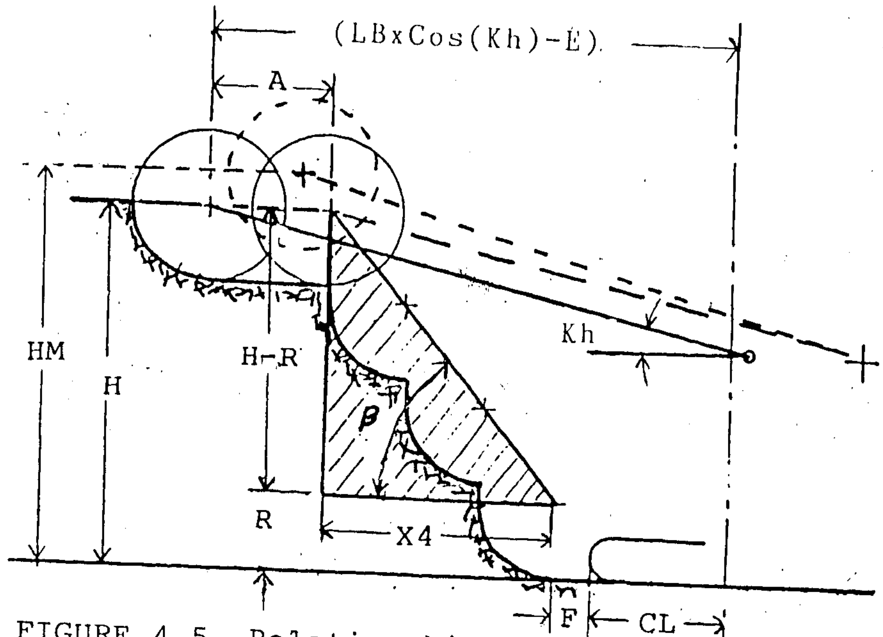
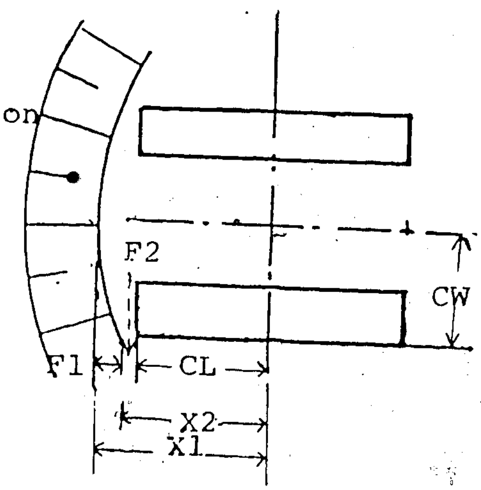


FIGURE 4.5 Relationship between the front face and the BWE design parameters

FIGURE 4.5a Determination of the safety distance between the crawler and the slope toe



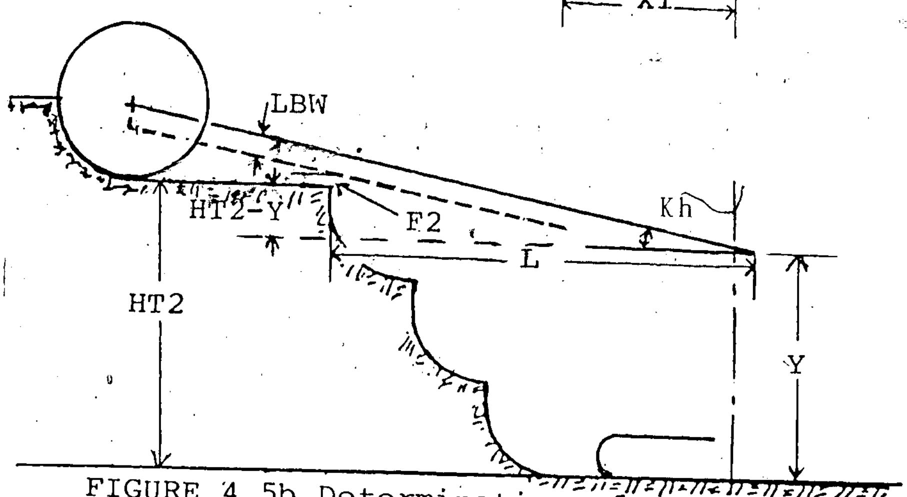


FIGURE 4.5b Determination of the distance L to prevent interference between the load boom and the second terrace

To avoid crawler damage, a safety distance F, (see figure 4.5a), is established as:

$$F=F1+F2 \qquad 4.3$$

where

F1 = Distance between the slope toe measured at the BWE centreline of advance, and the slope toe at the actual crawler location

F2 = Safety distance between the slope toe and the leading edge of the excavator crawler, (usually assumed to be one meter)

The value of F1 is defined by

$$F1=Z1-Z2 \qquad 4.3a$$

where

$$Z1=LBxCos(Kd) \qquad 4.3b$$

$$Z2=LBxCos(Kd)*Cos(\varphi o) \qquad 4.3c$$

and the offset slew angle φo is

$$Sin(\varphi o)=CW/LBxCos(Kd) \qquad 4.3d$$

All other symbols have been defined in Section 4.1.

There is no danger of load boom damage if the height of the second terrace crest (HT2) conforms to:

$$HT2 \leq (Y-LBW-F2) \tag{4.4}$$

If HT2 is greater than that defined by equation 4.4, the distance L in figure 4.5b is required:

$$L=((HT2-Y)+F1+F2)/Tan(Kh) \tag{4.5}$$

where

$$HT2=(H-R) \tag{4.5a}$$

$$F1=LBW/Cos(Kh) \tag{4.5b}$$

F2 (in equations 4.4 and 4.5) is a safety distance between the terrace crest and the load boom structure, (assumed as one half meter), and R is the digging wheel radius. Other symbols are detailed in Section 4.1. To determine the minimum front slope angle, the digging wheel centres are used. This method of defining slope angles has been used by other authors; Birkheuer (1983), Golosinski (1983), and Hillesheim (1979). If the interference between the excavator crawlers and the slope toe limits the minimum front slope angle, it can be defined by the relationship, (see figure 4.5):

$$Tan(\beta min)=(H-R)/([LBxCos(Kh)-E]-[CL+F]) \tag{4.6}$$

where H is the bench height, R is the digging wheel radius, and F is defined by equation 4.3. However, this definition of the minimum front slope angle does not permit advance of the BWE into the face. To ensure advancement, the following equation must be used:

$$Tan(\beta min)=(H-R)/([LBxCos(Kh)-E]-[CL+F+A]) \qquad 4.7$$

where A is the advance of the wheel into the mining face. By using equation 4.7, the minimum front slope angle can be defined for a given advance.

The maximum advance used in equation 4.7 may be limited by the interference between the load boom and the crest of the second terrace. If this happens, the value of A in equation 4.7 is:

$$A=[LBxCos(Kh)-E]-L \qquad 4.8$$

where L is defined by equation 4.5, (see figure 4.5b).

Another important limitation is the maximum advance the excavator can make into the face. The minimum front slope angle is a function of advance; therefore, it can be used to find the maximum advance relationship. Using equation 4.4, maximum advance (A) is defined as:

$$A=[LBxCos(Kh)-E]-[(H-R)/Tan(\beta)]-CL-F \qquad 4.9$$

β is the given front slope angle and all other variables are as previously defined. Again if the maximum advance is limited by the interference between the load boom structure and the crest of the second terrace, the maximum advance is defined by equation 4.5.

4.2.3 *Side Slope Angle*

The side slope of a BWE cut stays open for extended periods of time; therefore, its stability is of major concern. To prevent failures, a safe side slope angle should be defined and the ability of a BWE to form this side slope confirmed. For any given BWE, the range of side slope angles it can form is:

$$\alpha_{min} \leqslant \alpha \leqslant 90^{\circ} \qquad 4.10$$

The ability of an excavator to form a side slope is limited by the design of the digging head. On the sides of the digging wheel, there is usually a conveyor belt and a wheel drive protruding beyond the wheel contour, (see figure 4.6). To avoid interference between these components and the slope, the digging wheel must be swung at least to a minimum slew angle, min. This minimum slew angle can be defined as:

$$\psi_{min} = 90^{\circ} - \delta \qquad 4.11$$

The important value of δ is on the slope side of the BWE centreline, because it will be on this side that the interference occurs.

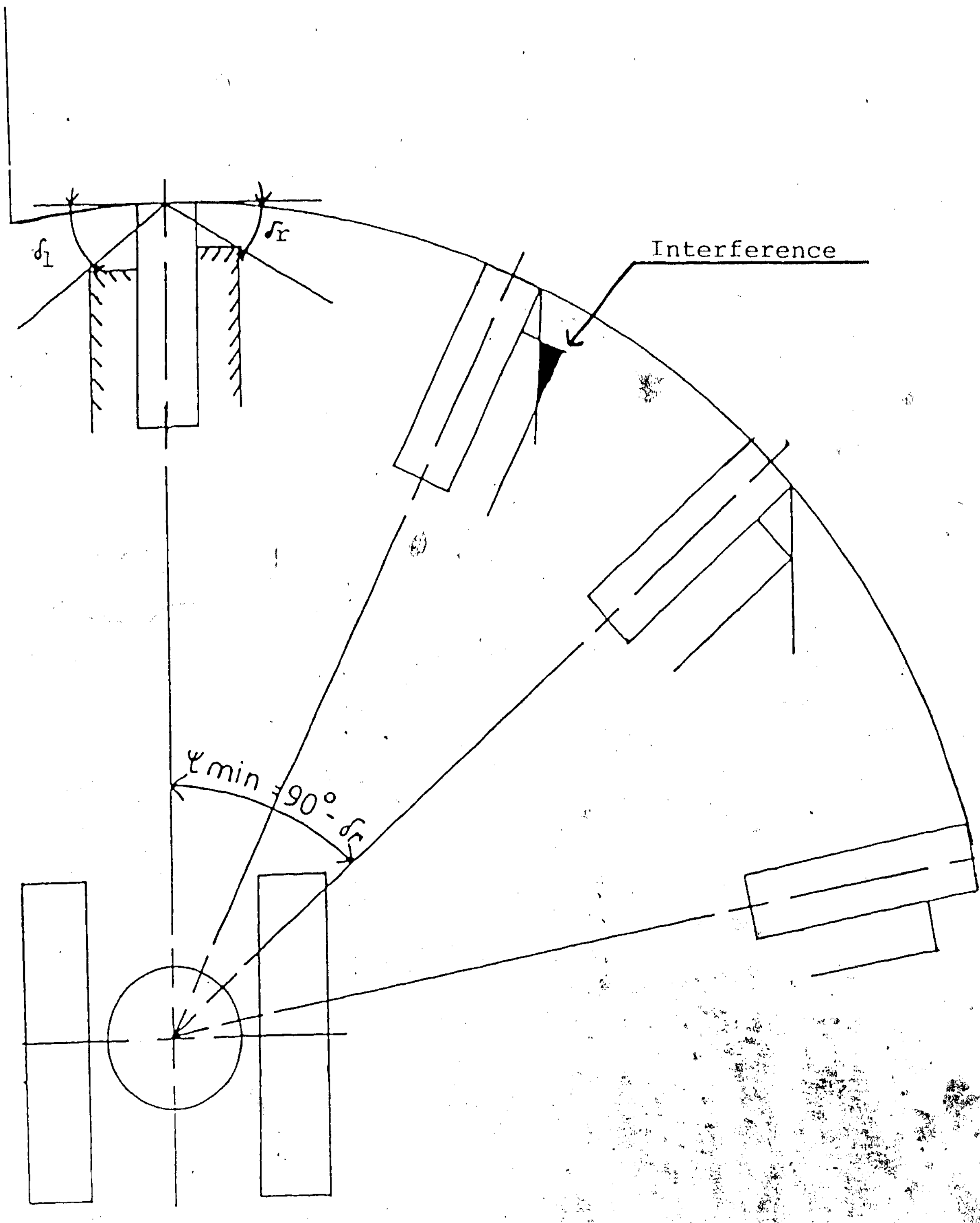


FIGURE 4.6 Minimum slew angle

The side slope angle is formed by slewing the digging wheel to different angles on each terrace (see figure 4.7). The minimum slew angle on the bottom terrace is limited by equation 4.11. As a result, the minimum distance between the excavator centreline of advance and the side slope toe is LB''min, (as shown in figure 4.7). The maximum slew angle on the other hand, occurs on the top terrace. The maximum reach of the wheel is obtained with a maximum practical slew angle of 90 degrees. This position of the wheel defines the maximum distance between the crest of the side slope and the excavator centreline of advance, LB'max in figure 4.7. Knowing these values and the bench height, the minimum side slope angle, αmin, that can be formed is:

$$Tan(\alpha min)=H/(LB'max-LB''min) \quad 4.12$$

where

H	=	Slope height
LB'max	=	Maximum reach of the load boom and the digging wheel at the maximum given slew angle
LB''min	=	Minimum required distance between the BWE centreline of advance and the side slope toe (defined by digging head design)

The values of LB'max and LB''min are:

$$LB'max=[LBxCos(Kh)-E+R]xSin(\varphi s) \quad 4.13a$$

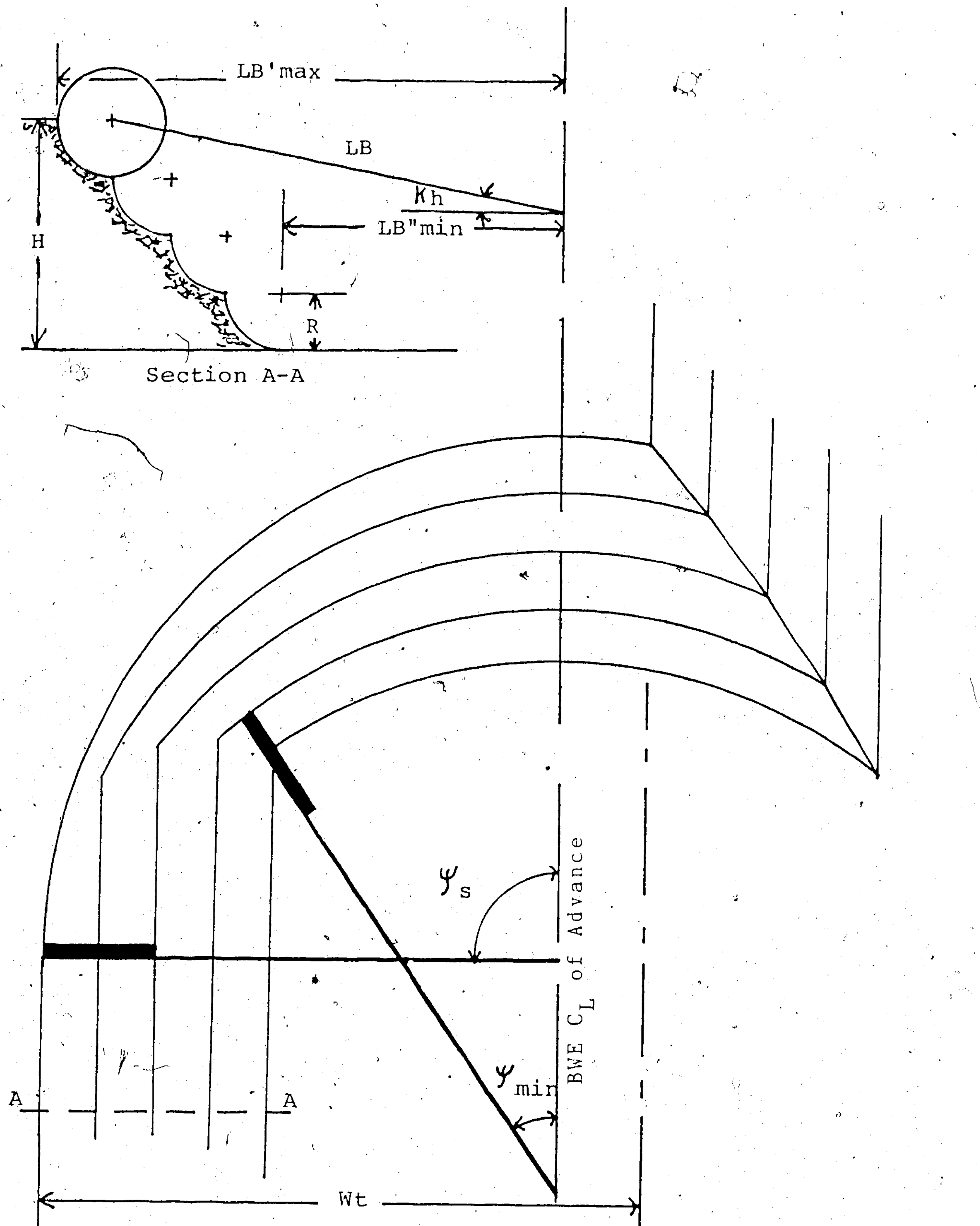


FIGURE 4.7 Minimum side slope angle for the terrace cut

and

$$LB''min=[LB \times Cos(Kd)-E] \times Sin(\psi min) \qquad 4.13b$$

where

R	=	Radius of digging wheel
ψs	=	Maximum slew angle on the slope side of the BWE centreline of advance
ψmin	=	Minimum slew angle defined by digging head design (determined using equaiton 4.11)

All other variables are as previously defined.

4.2.4 *Cut Width*

The width of a block mined by a BWE not only depends on the BWE design parameters, but also on the bench height, side slope angle and the slew angle on both the slope side and pit side of the BWE. The block width can be measured either at the top or at the bottom of the bench; Wt and Wb in figure 4.8.

The block width at the top of the bench is used for further analysis. Referring to figure 4.8, the block width (Wt) can be divided into two components, one on either side of the BWE centreline of advance, (Wt' and Wt'').

The maximum block width on the slope side of the BWE centerline, Wt', is excavated when the wheel slews a full 90

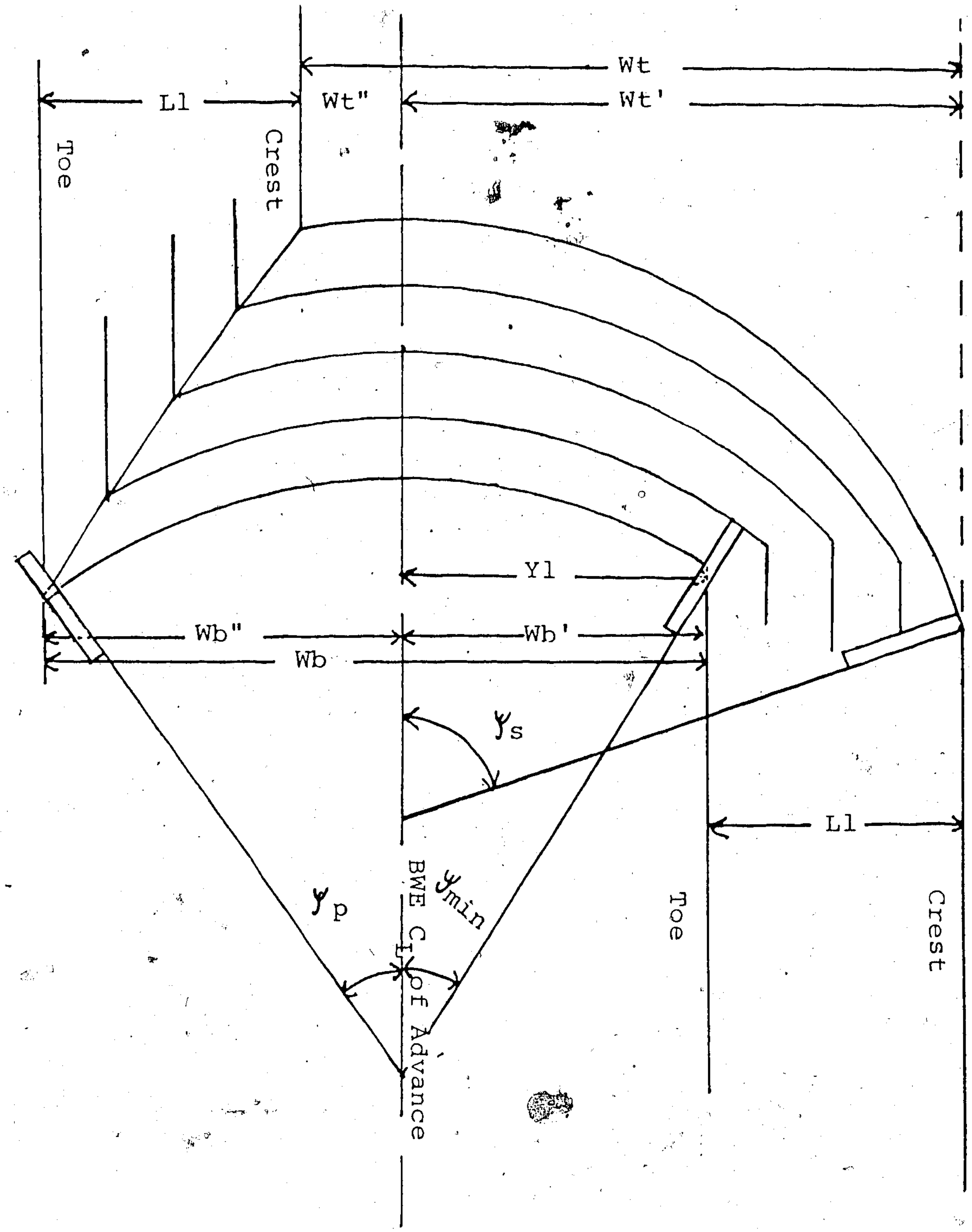


FIGURE 4.8 Determination of the terrace cut width

degrees on the top terrace. This maximum width can be defined as:

$$Wt' = LB \times Cos(Kh) - E + R \qquad 4.14a$$

where R is the radius of the digging wheel to the cutting lips. In practice, the load boom is not always swung the full 90 degrees; therefore, a more general equation is:

$$Wt' = [LB \times Cos(Kh) - E + R] \times Sin(\varphi s) \qquad 4.14b$$

where φs is the maximum slew angle measured on the slope side (of the BWE centerline) at the top of the bench.

When calculating Wt', the minimum slew angle, φmin cannot be ignored. To ensure that a given side slope angle can be formed, the following must hold true:

$$(Wt' - L1) \geqslant Y1 \qquad 4.15$$

where

$$L1 = H/Tan(\alpha) \qquad 4.15a$$

$$Y1 = [LB \times Cos(Kd) - E] \times Sin(\varphi min) \qquad 4.15b$$

and

Wt' = Width of block at the top of the bench, measured on the slope side of the BWE, (equation 4.14b)

H = Slope height

α = Side slope angle

ψ_{min} = Minimum slew angle defined by digging head design (equation 4.11)

The block width on the pit side of the BWE centreline of advance is defined using the maximum slew angle on the bottom terrace, ψp. From figure 4.8, the maximum block width at the bottom of the pit side is:

$$Wb''=[LBxCos(Kd)-E]xSin(\psi p) \qquad 4.16$$

Based on this equation, the width on the pit side of the BWE at the top of the bench, Wt", can be defined as:

$$Wt''=Wb''-L1 \qquad 4.17$$

where L1 is defined by equation 4.15a, and Wt' by equation 4.14b

The total block width can now be defined as:

$$Wt=Wt'+Wt'' \qquad 4.18$$

4.3 Dropping Cut

4.3.1 *Introduction*

The ability of a BWE to form dropping cut slopes is limited by:

1/ Minimum front slope angle as a function of bench height and depth of advance

2/ Maximum advance as a function of bench height and front slope angle

3/ Minimum and maximum side slope angles as a function of bench height

4/ Width of cut as a function of bench height and side slope angle

The above relationships are important in mining slope design, and in the selection of a BWE capable of forming the required slopes. To aid in the quantitative definition of these limits, computer programs are developed in Chapter 5 incorporating the relationships developed within this section.

Calculation of the load boom inclination is important to the development of the relationships within this section. The lowest load boom inclination, given by equation 4.1a is still valid; however, for other digging wheel locations, the load boom inclination must be calculated slightly different from those given by equations 4.1b/c/d. In a dropping cut, the digging wheel is located a distance R above the actual cut height; therefore modification of equations 4.1b/c/d yields:

$$Sin(Kh)=(HM-Y)/LB \text{ if } (H+R)\geqslant HM \qquad 4.19a$$

$$Sin(Kh)=((H+R)-Y)/LB \text{ if } (H+R)<HM \text{ and } (H+R)\geqslant Y \qquad 4.19b$$

$$Sin(Kh)=(Y-(H+R))/LB \text{ if } (H+R)\leqslant Y \qquad 4.19c$$

All variables are as previously defined.

4.3.2 *Front Slope Angle and Advance*

The maximum bench height (Hdmax) to which a dropping cut can be used, is defined as:

$$Hdmax=HM-R \qquad 4.20$$

If a bench is higher than Hdmax, the top portion of the bench must be removed with a terrace cut. It is assumed this terrace cut does not influence the dropping cut portion of the slope; therefore, if the bench height is greater then Hdmax, the value of the slope calculated at Hdmax is assigned to it.

The relationship between the BWE design parameters and the front mining face, is a function of both excavator advance and slope angle, (as outlined in Section 4.2.2).

Two limitations result from this inter-relationship:

1/ Minimum front slope angle as a function of bench height and excavator advance

2/ Maximum advance as a function of bench height and front slope angle

Starting with the first limitation, three limits on the advance must be imposed:

1/ Interference between the crawler and the slope toe must be prevented

2/ Interference between the load boom and the slope crest must be avoided

3/ The maximum depth of advance, A, should not exceed 0.7 times the digging wheel diameter

Interference between either the crawler and the slope toe, or the load boom and the slope crest, can result in damage to the excavator crawlers or load boom. To prevent this damage, the maximum advance of the excavator into the face, and consequently the minimum front slope angle, may be limited by these considerations.

A maximum advance of 0.7 times the digging wheel diameter limits the number of buckets digging at one time, and assures there is adequate power available for both cutting and lifting of the material (Venkataramani, 1970).

This factor of 0.7 is also recommended as the maximum terrace height in a terrace cut. In some circumstances, an operator may want to exceed the 0.7 factor. This can be done subject to an absolute maximum obtainable advance equal to the digging wheel diameter.

The minimum front slope angle is calculated using the digging wheel centers, (see figure 4.9), thus, it can be calculated simply as:

$$\tan(\beta min) = H/X4 \qquad 4.21$$

where

β min	=	Minimum front slope angle
H	=	Height of front slope (not to exceed Hdmax defined by equation 4.20)
X4	=	The horizontal distance of the front slope

The distance X4 is subject to restrictions placed on it by the maximum advance limitations given earlier. The general form of this distance is:

$$X4 = [LB \times \cos(Kh) - E] - CL - F - A \qquad 4.22$$

where, F is given by equation 4.3, and A is the advance (maximum of 0.7 times the digging wheel diameter). If interference occurs between the load boom and the slope crest, maximum advance, A, is defined by equation 4.8.

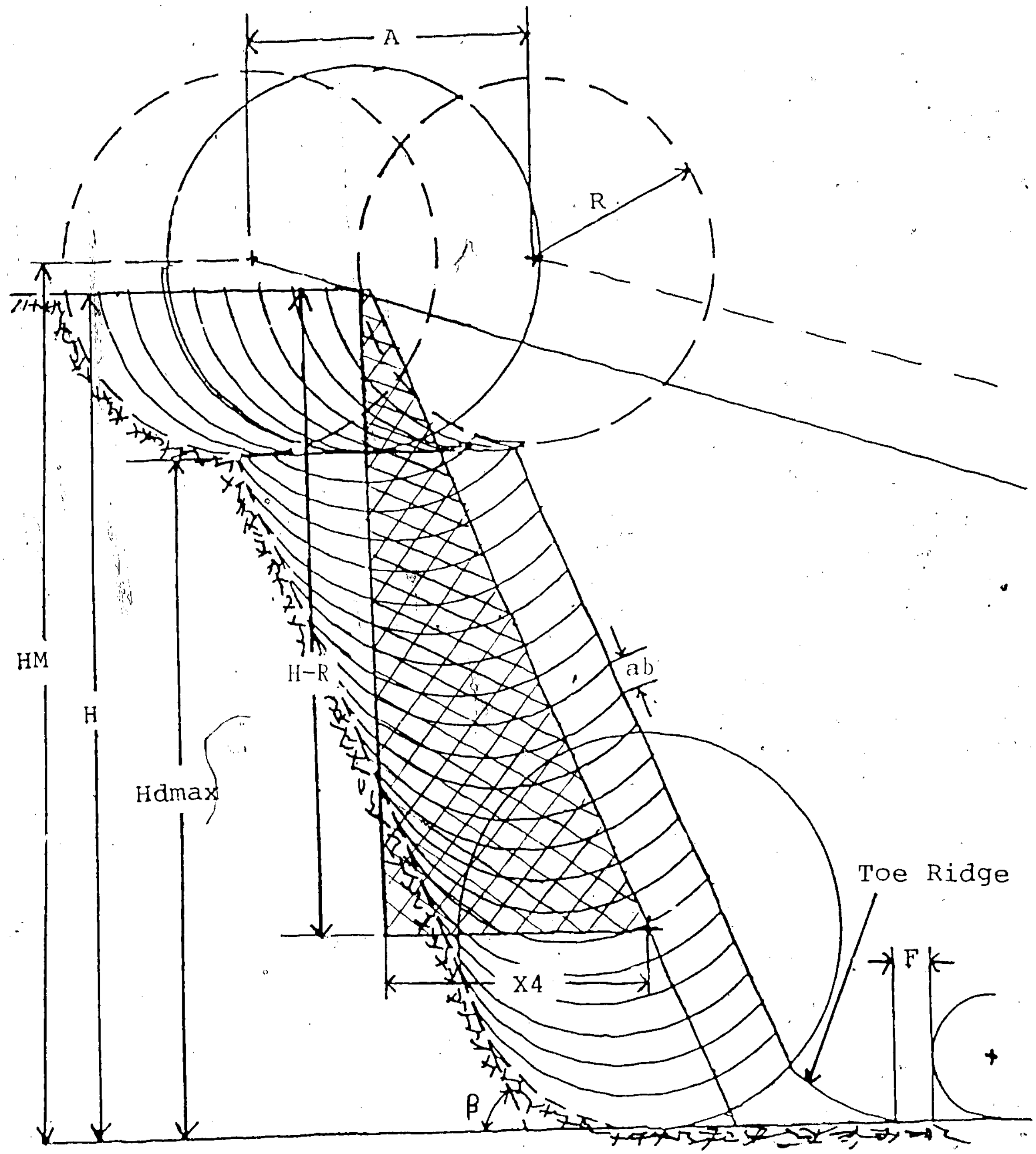


FIGURE 4.9 Formation of the front slope using a dropping cut

The minimum front slope angle is a function of advance; therefore, it can be used to find the maximum advance relationship. Using the first limitation, (interference between the crawler and slope toe), the maximum advance is:

$$A=[LBxCos(Kh)-E]-[H/Tan(\beta)]-CL-F \qquad 4.23$$

where, β is the given front slope angle and F is defined by equation 4.3. If the maximum advance is limited by the interference between the load boom structure and the slope crest, then:

$$A=[LBxCos(Kh)-E]-L \qquad 4.24$$

where L is defined by equation 4.5.

Both equations 4.23 and 4.24 are limited to a maximum advance of 0.7 times the digging wheel diameter.

The distance the excavator must retreat from the face to form the required front slope angle must also be investigated. To form the front slope, the load boom pivot point must be moved the proper distance, (Rodgers, 1971). This distance, (X1 in figure 4.10), is measured at the elevation of the load boom pivot point, and has a value of:

$$X1=X4+X2-X3 \qquad 4.25$$

where,

$$X4=H/Tan(\beta) \qquad 4.26a$$

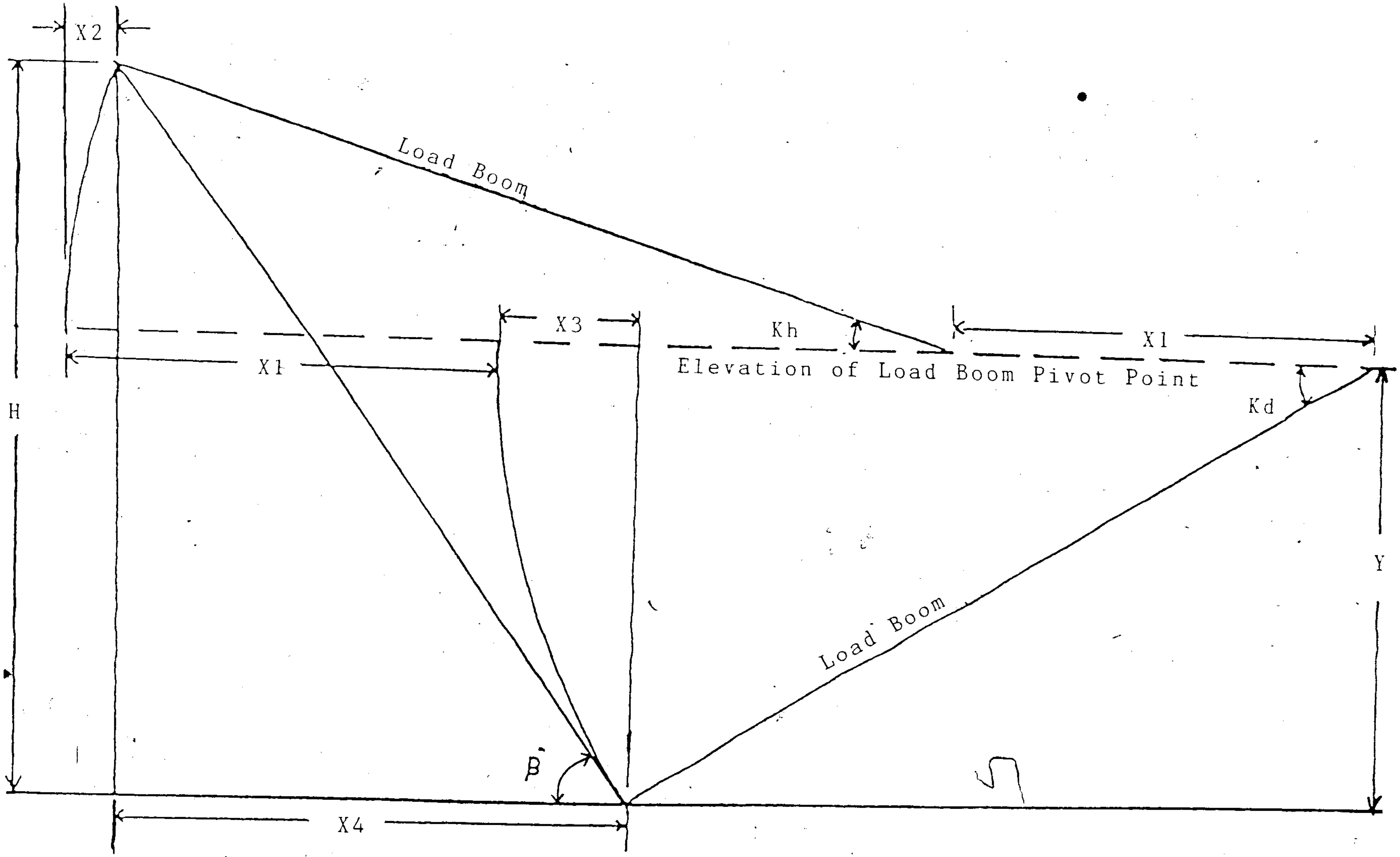


FIGURE 4.10 Determination of the distance X1

X2=[LB-LBxCos(Kh)] 4.26b

X3=[LB-LBxCos(Kd)] 4.26c

The bench height H in equation 4.26a must not exceed Hdmax; all other variables have been previously defined.

4.3.3 *Side Slope Angle*

The determination of relationships for the minimum and maximum side slope angles is complex. Rodgers (1971, 1976) pointed out the difficulties encountered by the State Electricity Commission of Victoria (SECV), Australia. The method used by SECV to solve these problems, was to use scale drawings or construct plasicine slopes. These methods are accurate, but time consuming; therefore, this study attempts to determine mathematical relationships to describe the side slope angle range.

Before the determination of the mathematical relationships, it is important to be familiar with how the slope looks as it is being formed, and after it has been completed.

By reducing the slew angle on each slice down the face, a series of steps is formed by the digging wheel, see figure 4.11. If a cross-section is taken through these steps, section X-X, a critical slope angle, αc, must be maintained in order to prevent damage to equipment protruding beyond

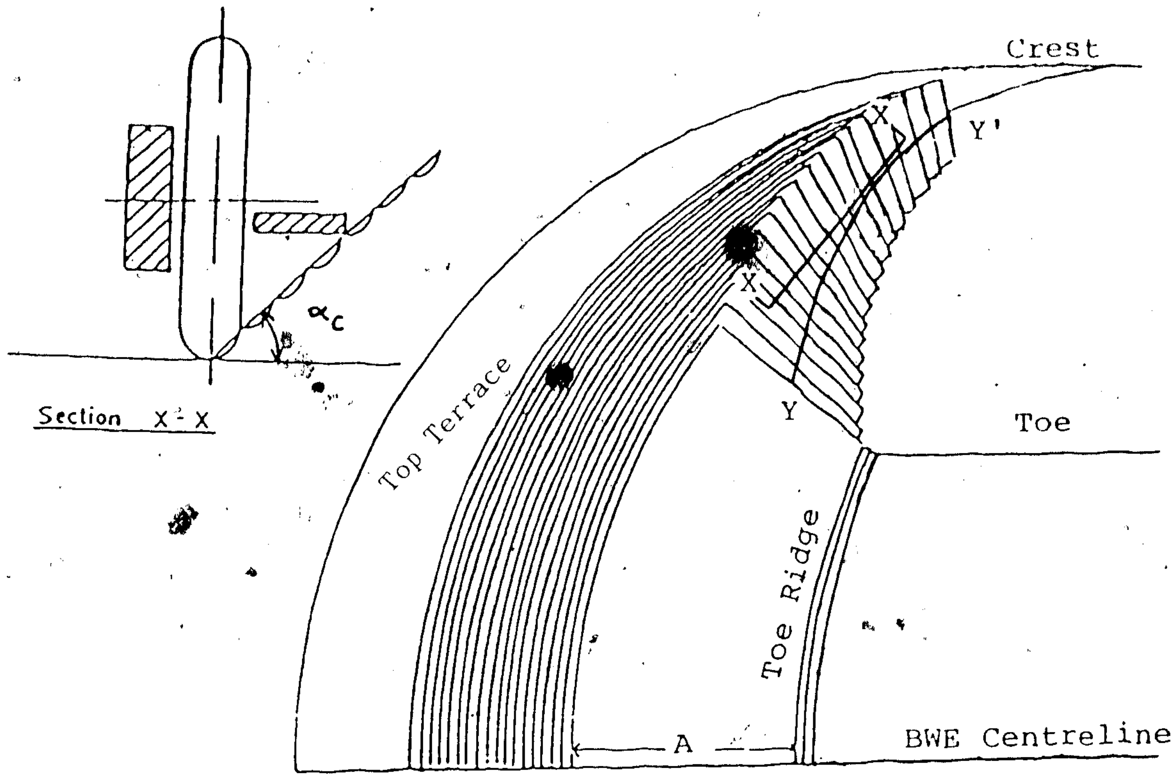


FIGURE 4.11 Location of the critical side slope angle

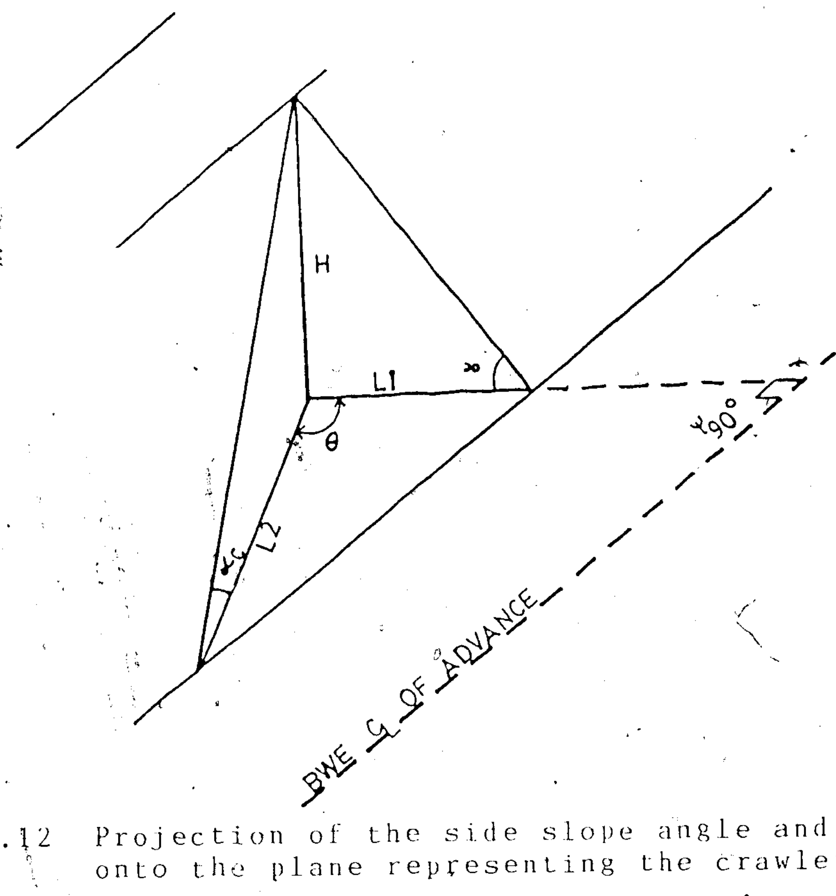


FIGURE 4.12 Projection of the side slope angle and length onto the plane representing the crawler level

the contour of the digging wheel. This critical angle is defined as the vertical wheel free angle (VWFA) as outlined in Section 4.1.3.

By connecting the centres of each step, a curve is formed, (Y-Y' in figure 4.11). It is along this curve that the VWFA cannot be exceeded. This forms the basis for the models outlined in this section.

The related geometry may be simplified by projecting the slopes and angles down onto a plane represented by the crawler level, as illustrated in figure 4.12. L1 is the projection of the actual side slope angle, (measured perpendicular to the BWE centreline of advance), and is defined as:

$$L1=H/\tan(\alpha) \qquad 4.27$$

where

L1	=	Length of side slope angle projection
H	=	Slope height
α	=	Side slope angle

Line L2 is defined similarly, except that the side slope angle is taken at an offset angle, θ, from line L1 and is:

$$L2=H/\tan(\alpha\theta) \qquad 4.28$$

where

L2	=	Projected length of side slope at the

offset angle θ

α_θ = Side slope angle at offset angle

To develop the relationship describing the side slope angle for a dropping cut, the distance between the BWE centreline and the actual slope is required. Using figure 4.13, the distance can be calculated as:

$$[LB \times \cos(K) - E] + RD \qquad 4.29$$

where, the first part of the expression is the distance to the digging wheel centre, and RD is the distance between the digging wheel centre and the actual slope.

The relationship used to define RD depends on the bench height used. Refering to figure 4.13, the bench height can be divided into three zones; defined as:

1/ $0 \leq H \leq (HS+H2)$ 4.30a

2/ $(HS+H2) < H \leq HM$ 4.30b

3/ $H > HM$ 4.30c

In Zone One, (defined by equation 4.30a), the side slope angle, (measured from point C to point G); is parallel to the angle formed by the digging wheel centres, (measured from point A to point B); therefore, within this zone, the

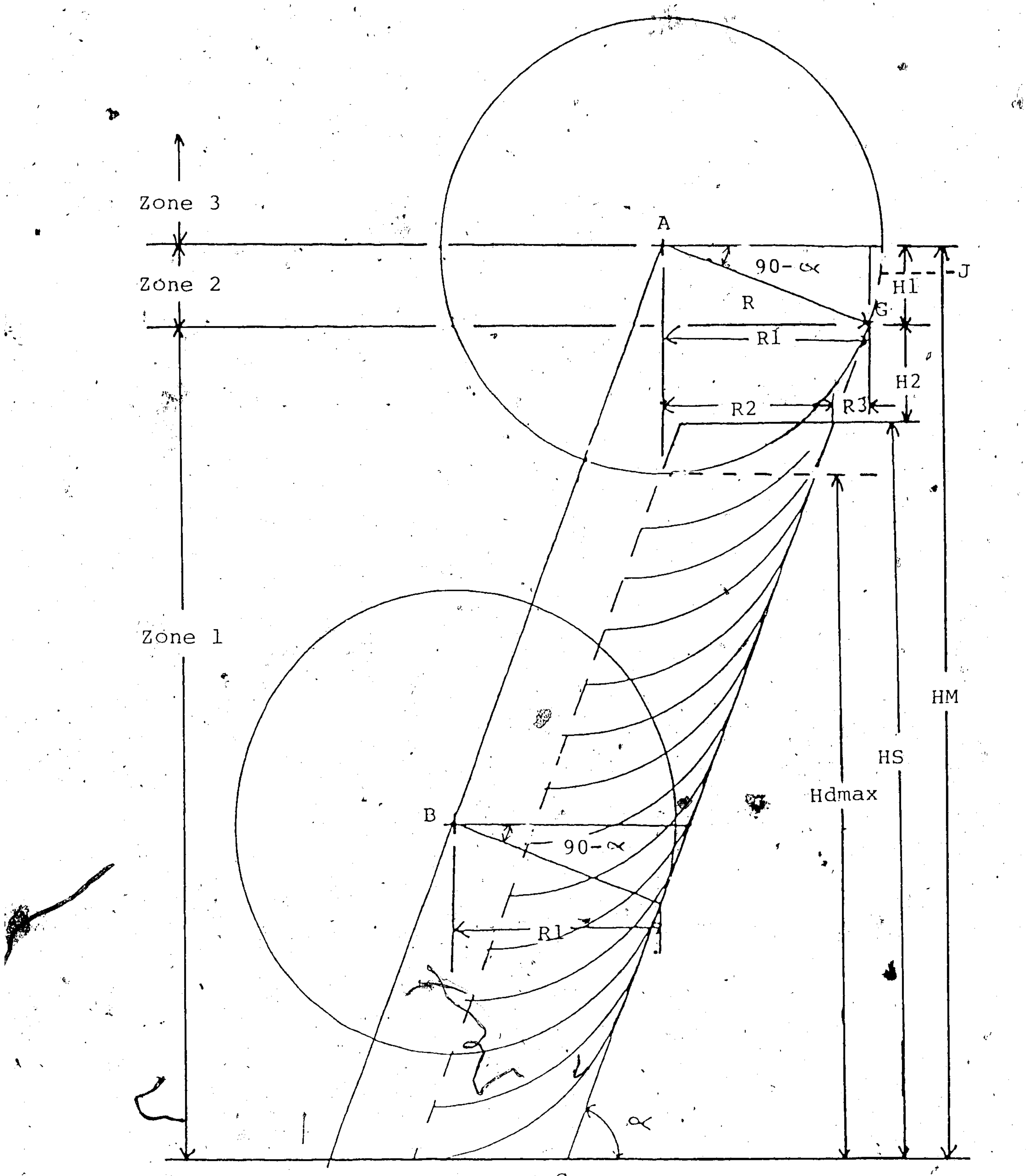


FIGURE 4.13 Relationships between the digging wheel and the actual side slope for a dropping cut

value of RD in equation 4.27 can be set as:

$$RD=0 \qquad 4.31$$

For a bench height in Zone two, the distance to the actual slope must be defined. In this zone the side slope is measured from the toe of the slope at the point C, to the crest of the slope (point J), located within Zone Two. The distance to point C is:

$$RD=R1 \qquad 4.32a$$

and to point J

$$RD^2=R^2-(HM-H)^2 \qquad 4.32b$$

In the above equations:

R1=R[illegible](90-α) 4.33a

$$H2=R-ab-H1 \qquad 4.33b$$

$$HS=Hdmax+ab \qquad 4.33c$$

$$H1=R \times Sin(90-\alpha) \qquad 4.33d$$

R is the digging wheel radius, ab is the depth the wheel drops on each slice, and α is the side slope angle.

If the bench height is located in Zone Three, the side slope forms an overhang which usually breaks off. Because of this, it is assumed the side slope angle defined at a bench height of HM, is valid for all bench heights greater than HM.

These relationships will be used throughout this section.

Model A

As stated previously, connecting the centre points of the steps, formed by the digging wheel as it moves down the face, forms a curve. The placement of line L2, and consequently the value of the offset angle, must be set with this in mind. The first consideration in establishing the location of line L2 is to find a model to describe the curve Y-Y'. As a first assumption, this curve is represented by a straight line.

Model A assumes line L2 is fixed at one end by the point A, and on the other by any point along the arc B-B', (see figure 4.14). To locate Point A, the distances (L1+Y1) and X5 are required. Using point C as a starting point:

$$X5=[LB\times Cos(Kh)-E]\times Cos(\Psi s) \quad 4.34$$

and

$$(L1+Y1)=[LB\times Cos(Kh)-E]\times Sin(\Psi s) \quad 4.35$$

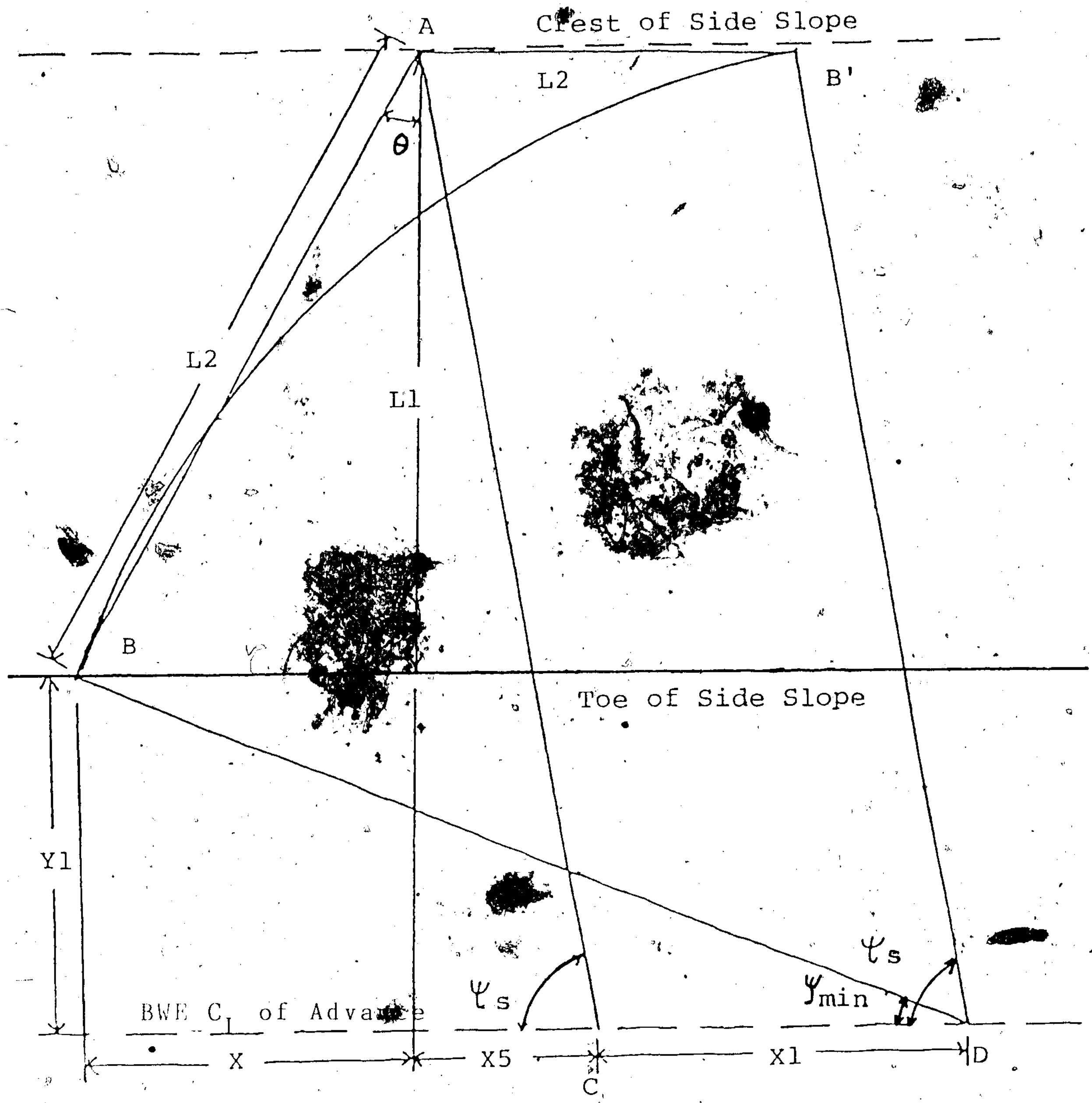


FIGURE 4.14 Location of Line L2 and Arc B-B' for Model A

where, Y1 is the minimum distance between the BWE centreline and the side slope toe; all other variables are as defined previously.

The location of arc B-B′ depends on the distance X1 given by equation 4.25 in Section 4.3.2. By moving a distance X1 along the BWE centreline of advance, a new point D is established. This point becomes the centre point for the placement of arc B-B′ with a radius of:

$$RB = LB \times \cos(Kd) - E \qquad 4.36$$

Point B is fixed by a minimum slew angle defined as:

$$\sin(\psi_{min}) = Y1/RB \qquad 4.37$$

where RB is given by equation 4.36, Y1 by:

$$Y1 = CW + F \qquad 4.38$$

and F is a safety distance between the excavator crawler and the side slope toe to prevent crawler damage. This minimum slew angle is established to prevent interference between crawler and side slope toe. Point B′ is fixed using the maximum slew angle applicable, (ψ_s).

The location of points B and B′′ can now be found. The following equations are used to determine the location of these end-points, (measured from Point D):

$$XB=[LBxCos(Kd)-E]xCos(\psi min) \quad 4.39a$$

$$YB=[LBxCos(Kd)-E]xSin(\psi min) \quad 4.39b$$

$$XB'=[LBxCos(Kh)-E]xCos(\psi s) \quad 4.39c$$

$$YB'=[LBxCos(Kh)-E]xSin(\psi s) \quad 4.39d$$

where the variables are as previously defined. The location of points B and B′ define the range of side slope angles that can be formed.

The influence of the critical side slope angle must be considered. For any digging wheel design, a critical side slope angle, αc, can be defined using the vertical wheel free angle, see Section 4.1.3. With this critical angle and the slope height, a minimum value for line L2 can be established as:

$$L2min=H/Tan(\alpha c) \quad 4.40$$

As stated previously, one end of line L2 is fixed at Point A. This point becomes the centre point for an arc, (G-G′), with radius L2min, (as shown in figure 4.15). The area where this arc crosses arc B-B′ (shaded area) defines the region where the excavator cannot form the side slope angles, because the actual length of line L2 is less than the calculated minimum value L2min. The range of side slope angles therefore, is defined as:

$$\alpha min1 \leqslant \alpha \leqslant \alpha max1 \text{ and } \alpha min2 \leqslant \alpha \leqslant \alpha max2 \quad 4.41$$

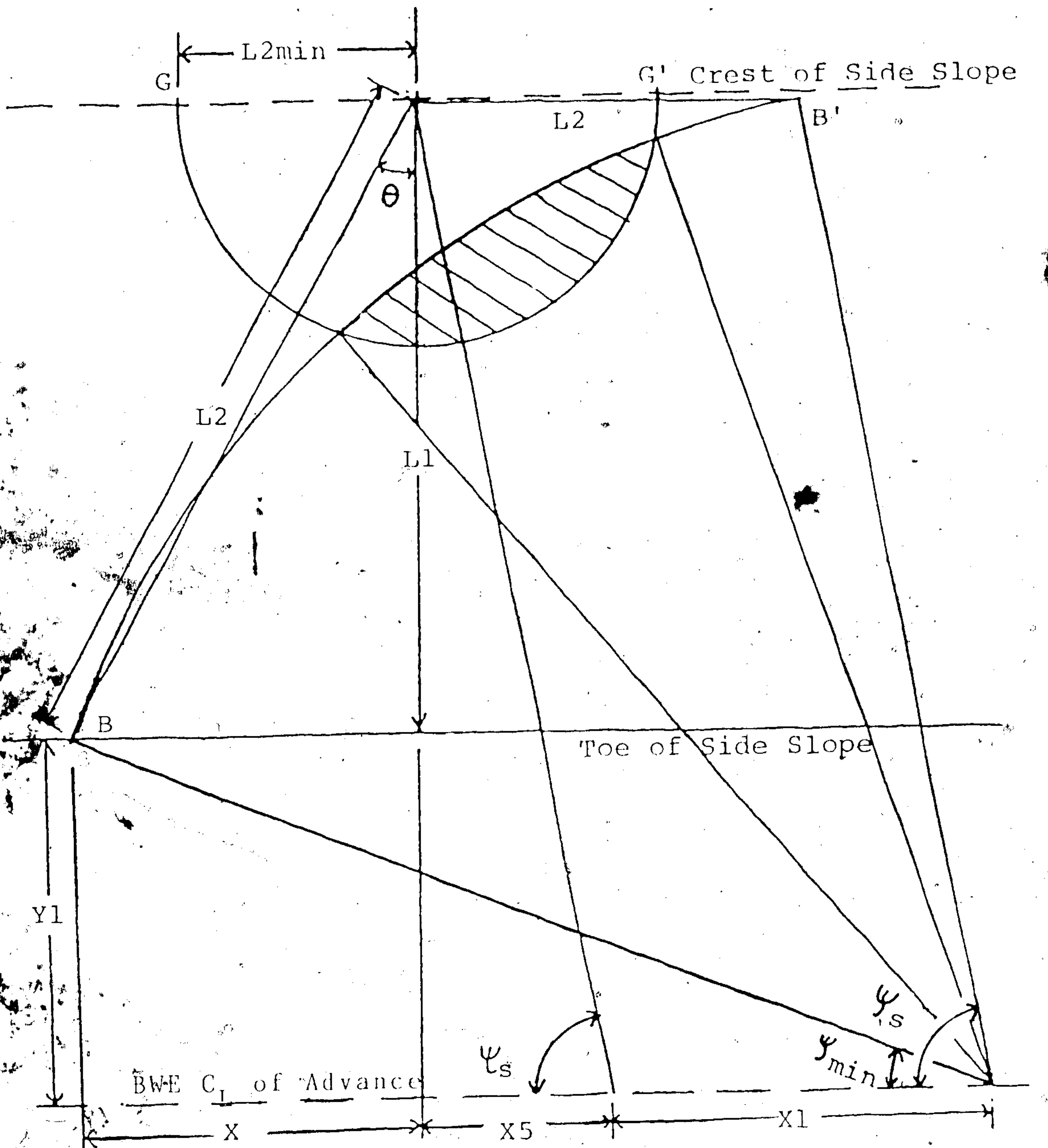


FIGURE 4.15 Placement of an arc representing the minimum length of line L2, and the area where the side slope angles cannot be formed

where

α_{min1} = Minimum possible side slope angle

α_{max1} = Lower intermediate limit of the side slope angle range.

α_{min2} = Upper intermediate limit of the side slope angle range

α_{max2} = Maximum possible side slope angle

To determine these side slope angle limits, figure 4.15 can be used.

To avoid damage to the excavator crawlers, a minimum slew angle must be established as in equation 4.37. Using this slew angle, the minimum side slope angle can be defined in the following manner:

To determine the minimum side slope angle, the maximum value of L1 is required. The maximum value is defined as:

$$L1=(L1+Y1)-Y1 \qquad 4.42$$

where

Y1 = The minumum distance between the BWE centreline of advance and side slope toe to prevent crawler damage

L1+Y1 = The maximum distance between the crest of the slope and the BWE centerline of advance

It is convenient to write equation 4.42 this way because:

$$(L1+Y1)=[LBxCos(Kh)-E]xSin(\Psi s) \qquad 4.43$$

and

$$Y1=[LBxCos(Kd)-E]xSin(\Psi min) \qquad 4.44$$

thus, obtaining the maximum value of L1. With this value, the minumum slope angle is:

$$Tan(\alpha min)=H/(L1+RD) \qquad 4.45$$

where H and RD are as defined at the start of this section.

The maximum side slope angle can also be defined using equation 4.42; however, Y1 is the maximum distance between the BWE centreline of advance and the slope toe; defined as:

$$Y1=[LBxCos(Kd)-E]xSin(\Psi s) \qquad 4.46$$

If L1 is zero or negative, the maximum side slope angle is set to 90 degrees, otherwise, the angle may be found using equation 4.45.

To define the intermediate limits of the side slope angle, the area where arcs G-G′ and B-B′ cross, can be located inside a box as in figure 4.16. By finding the slew angles to the edges of this box, (points a′ and b′), the values of the intermediate limit slew angles will be bounded. The following equations can be used to determine these boundary slew angles:

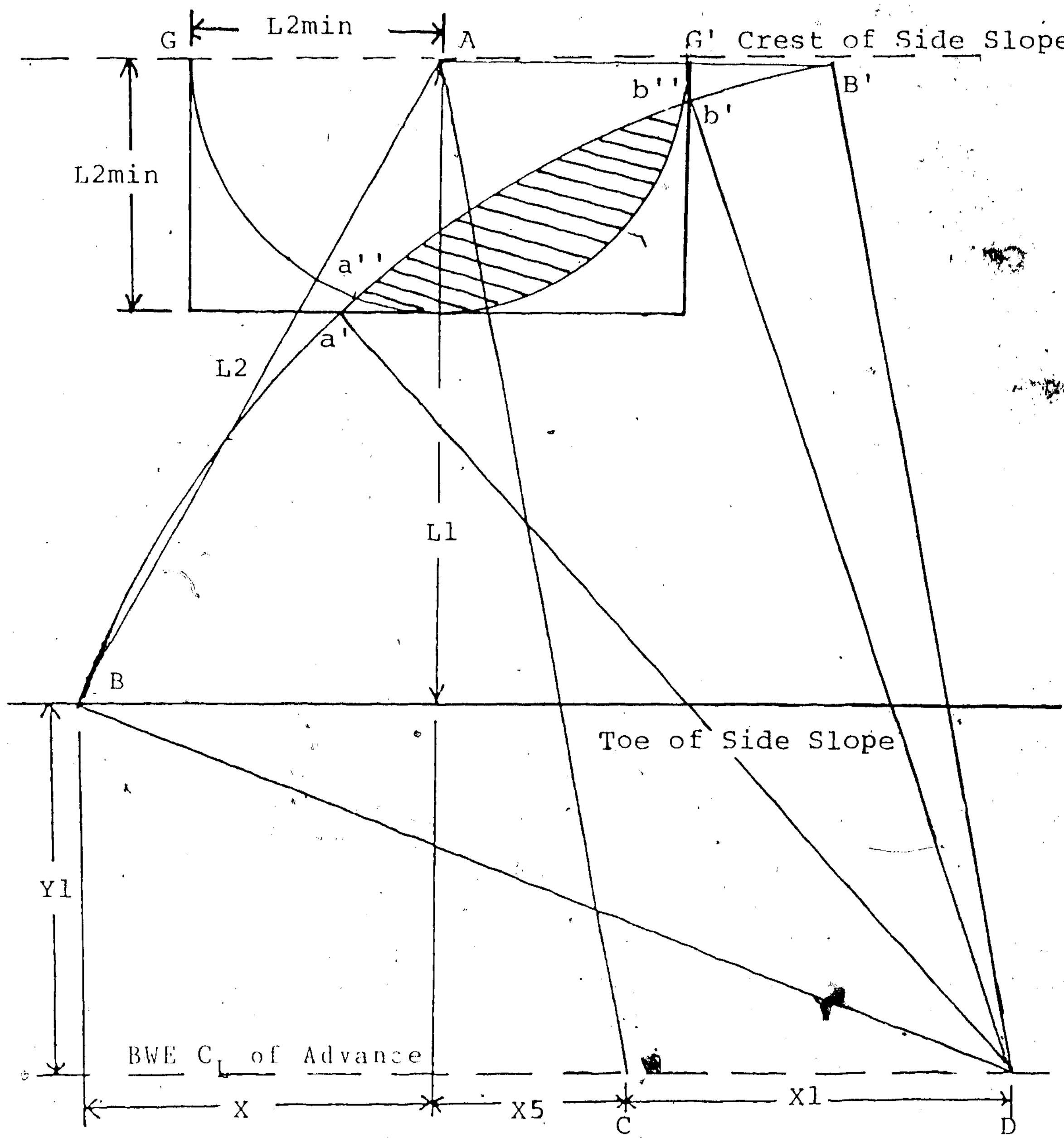


FIGURE 4.16 Method used to determine the intermediate limits of the side slope angle range for Model A

$$\mathrm{Sin}(SLa') = [(L1+Y1) - L2min] / [LB \times \mathrm{Cos}(Kd) - E] \qquad 4.47$$

$$\mathrm{Sin}(SLb') = (X1+X5-L2min) / [LB \times \mathrm{Cos}(Kd) - E] \qquad 4.48$$

where (L1+Y1) is defined by equation 4.43, L2min by equation 4.40, X1 by equation 4.25, and X5 by equation 4.34.

Once these boundary slew angles are defined, they can be used to determine the actual intermediate limit slew angles. The actual values of the intermediate slew angles, (a′′ and b′′), must be defined using an iterative method. The approach used is based on the fact that at the points a′′ and b′′, the following equation holds true:

$$L2 = L2min \qquad 4.49$$

L2min in the above equation is defined by equation 4.40 and L2 by:

$$L2^2 = L2X^2 + L1^2 \qquad 4.50$$

where

$$L2X = [LB \times \mathrm{Cos}(Kd) - E] \times \mathrm{Cos}(SL) - X1 - X5 \qquad 4.50a$$

$$L1 = (L1+Y1) - [LB \times \mathrm{Cos}(Kd) - E] \times \mathrm{Sin}(SL) \qquad 4.50b$$

and (L1+Y1) is defined by equation 4.35, X1 by equation 4.25, X5 by equation 4.34, and SL is the slew angle at a′′ or b′′.

Once the values of SLa'' and SLb'' are found, the corresponding side slope angles can be calculated using:

$$Tan(\alpha)=H/(L1+RD) \qquad 4.51$$

where H and RD are as defined at the start of this section, and L1 is defined by equation 4.50b.

At any given maximum slew angle, φs, and bench height, a particular BWE can form a range of side slope angles given by equation 4.41. Under specific geological conditions, however, the side slope angle required may fall within the range the excavator cannot form. This problem can be overcome by reducing the maximum slew angle φs. Figure 4.17 shows the area where arcs G-G' and B-B' cross has been reduced by lowering the maximum slew angle; all other parameters are kept constant.

Although the maximum slew angle can be reduced in an effort to form the required slew angle, it can only be reduced to a point defined as:

$$Sin(\varphi ms)=(CW+F+[H/Tan(\alpha)])/[LBxCos(Kh)-E] \qquad 4.52$$

where

φms	=	Minimum value of φs
α	=	Given side slope angle
F	=	Safety distance between the edge of the crawler and the side slope toe

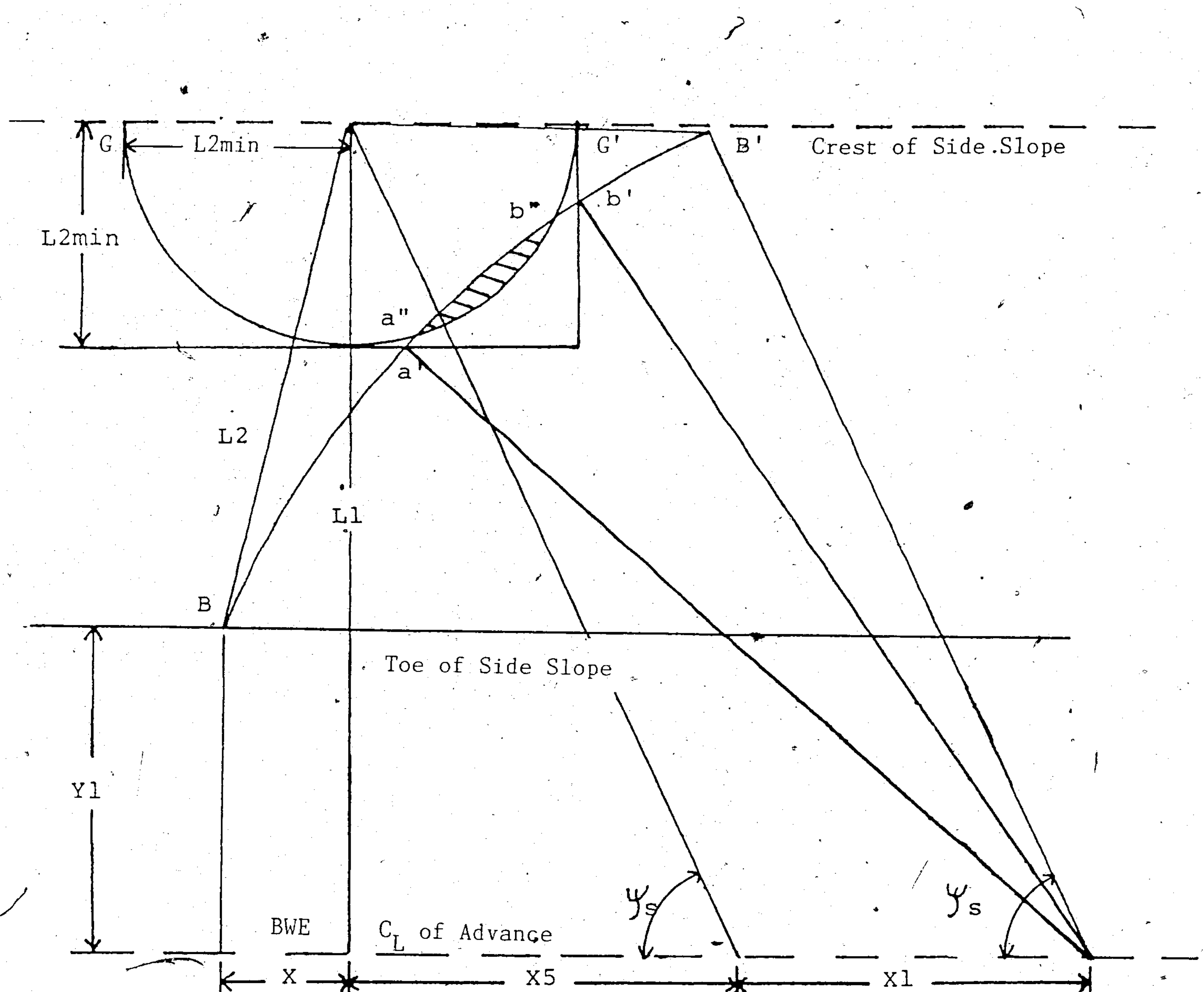


FIGURE 4.17 Effect of reducing the maximum slew angle on the side slope angle range (all other parameters kept constant) for Model A

The maximum slew angle must be kept greater then ms to prevent interference between the crawler and the slope toe.

Model B

In Model A, the development of the side slope angle assumed that line L2 has two fixed endpoints. Model B is similar, except L2 is fixed only to one end, that is, it must be fixed at any point along the arc B-B′, (see figure 4.18).

The direction of line L2 is assumed to be perpendicular to the load boom centreline, measured at the bottom of the bench. This assumption is used, because the critical side slope angle cannot be exceeded along this line, (line X-X in figure 4.19).

Using the definition above, the offset angle, θ, between line L2, and the actual slope length L1, is simply:

$$\theta = \varphi_{min} \qquad 4.53$$

where

θ = Offset angle

φ_{min} = Slew angle at bottom of slope

With the location of line L2 established, its actual length must be checked against the imposed limit L2min, (defined by equation 4.40). The actual length of line L2 is:

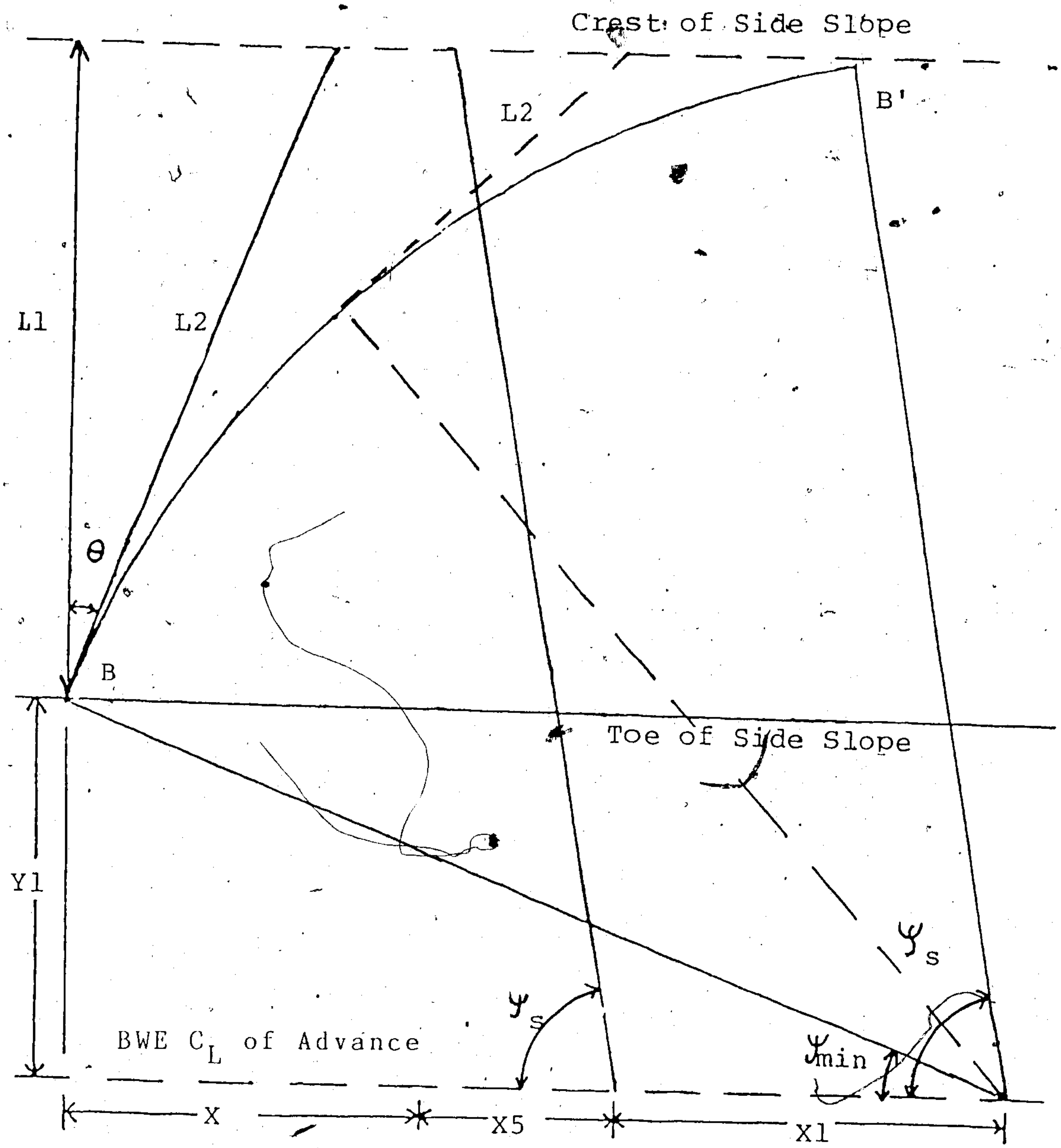


FIGURE 4.18. Location of line L2 and arc B-B' for Model B

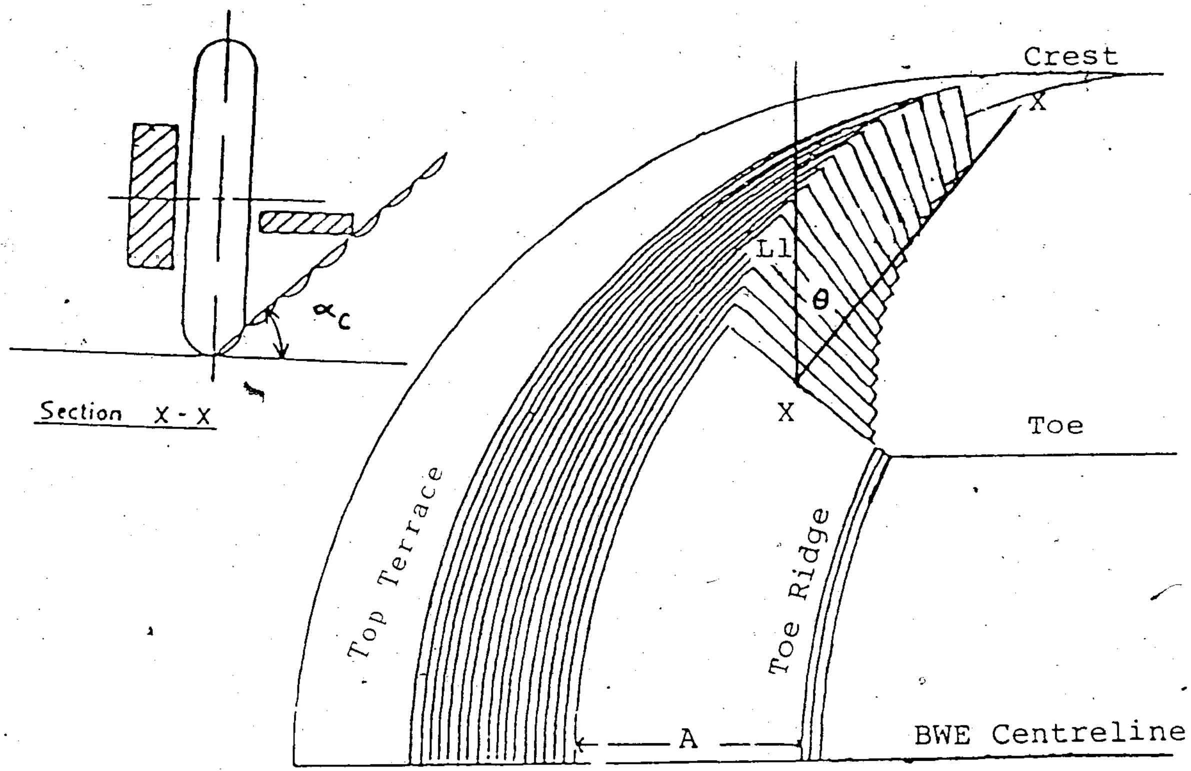


FIGURE 4.19 Location of the critical side slope angle for Model B

$$L2 = L1/\cos(\theta) \qquad 4.54$$

where L1 is defined using equation 4.27 and the offset angle, θ , has limits of:

$$\psi_{min} \leq \theta \leq \psi_s \qquad 4.55$$

where

ψ_{min} = Minimum slew angle imposed by excavator design (equation 4.45)

ψ_s = Maximum slew angle on the slope side of the BWE centreline

Depending on the slope height, side slope angle, maximum slew angle on the slope side, VWFA, and BWE design parameters, there is a range of side slope angles which also has the form given by the equation 4.41, that is:

$$\alpha_{min1} \leq \alpha \leq \alpha_{max1} \text{ and } \alpha_{min2} \leq \alpha \leq \alpha_{max2} \qquad 4.56$$

where

α_{min1} = Minimum possible side slope angle

α_{max1} = Lower intermediate limit of side slope angle range

α_{min2} = Upper intermediate limit of side slope angle range

α_{max2} = Maximum possible side slope angle

Figure 4.20 can be used to show equation 4.56 is valid. Because of the assumption used, as the slew angle increases, the length of line L2 decreases until a point is reached where L2 is a minimum. Increasing the slew angle beyond this point results in increased values for L2. This is shown in figure 4.20 as:

$$L2a > L2b < L2c \qquad 4.57$$

Moving one step further; if L2min is larger than the minimum value of L2 (L2b), there is a range where the side slope angles cannot be formed. Referring to figure 4.20:

$$L2a > L2min > L2b < L2min < L2c \qquad 4.57a$$

thus confirming the range given by equation 4.56.

The minimum and maximum values of the side slope angle, αmin1 and αmax2, given in equation 4.56 are defined in the same manner as in Model A.

As in Model A, the determination of the intermediate side slope limits requires an iterative method. These intermediate limit slew angles must first be bounded. The minimum slew angle possible for the lower limit, (point a' in figure 4.20), is defined by equation 4.47, while the maximum possible slew angle for the upper limit is given by the maximum slew angle φs. The actual values of the intermediate limit slew angles, a'' and b'', fall within

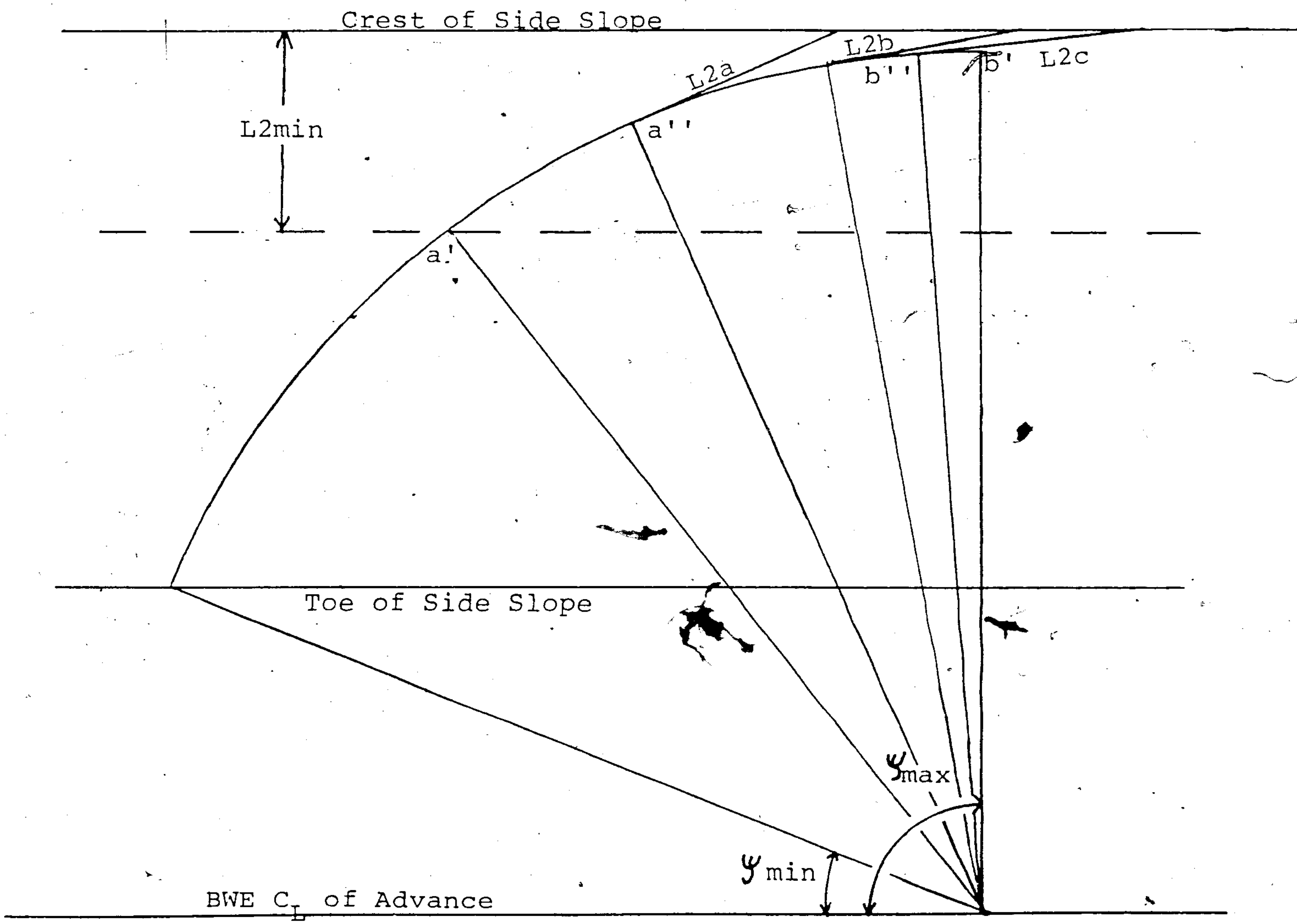


FIGURE 4.20 Validation of the range of side slope angles given for Model B

these boundry limits.

To define the slew angles at the actual intermediate limits, (a'' and b''), the following equation is again used:

$$L2=L2min \qquad 4.58$$

where, L2min is defined by equation 4.40, and L2 by:

$$L2=L1/Cos(SL) \qquad 4.59$$

L1 in the above equation is defined by equation 4.27, and SL is the slew angle at a'' or b''.

Once these limit slew angles are determined, the slope angle are calculated using:

$$Tan(\alpha)=H/(L1+RD) \qquad 4.60$$

where H and RD are as defined at the start of this section, and L1 is defined by equation 4.50b.

Model C

Model C employs the definition of the side slope angle used by the State Electricity Commission of Victoria, Australia, (see figure 4.21). In this method, L2 is not restricted to being a straight line from toe to crest as in Models A and B, but is made up of the segments. These segments are defined by the steps formed by the digging wheel as it moves down the face; therefore determination of the maximum and minimum side slope angles is more complex.

The minimum side slope angle for a given excavator is calculated as:

$$Tan(\alpha min)=H/([(LBxCos(Kh)-E+RD)xSin(\varphi s)]-Y1) \quad 4.61$$

where

H = Slope height (as defined at the start of this section

RD = Distance between the digging wheel centre and the actual slope crest (as defined at the start of this section)

and Y1 is defined by equation 4.44.

To ensure the minimum side slope angle given by equation 4.61 can be formed, a check is made. This check requires the interval length of line L1 on each step made

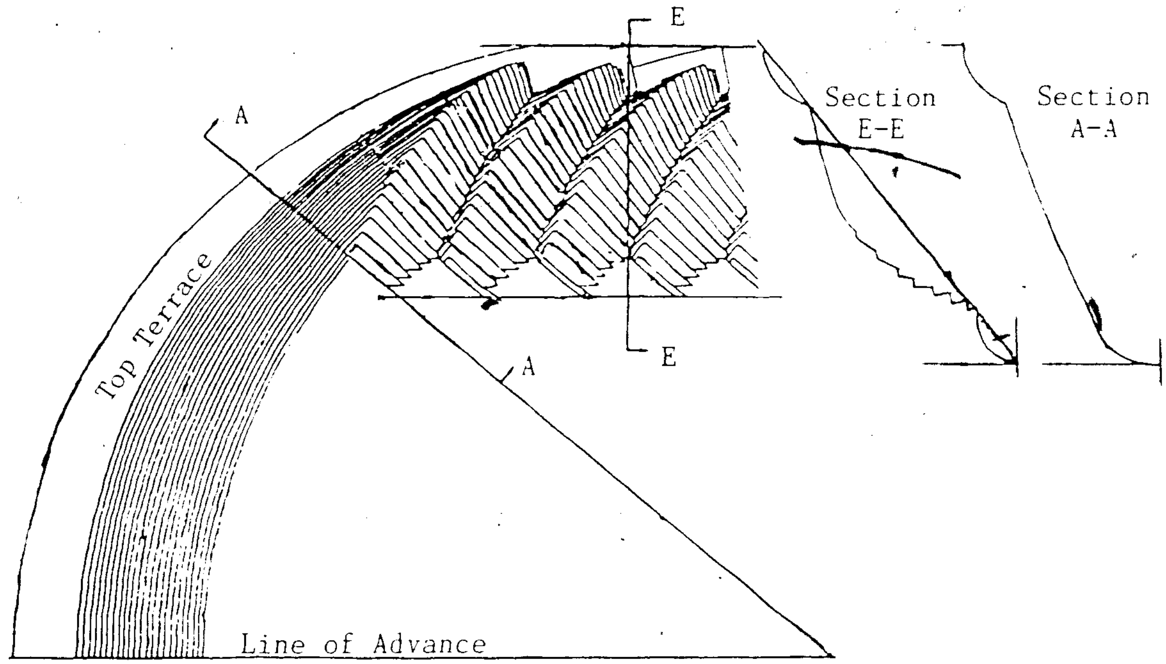


FIGURE 4.21 Shape of the side slope angle and how it is measured at SECV (after Rodgers)

down the face;

$$L1ab = ab/Tan(\alpha min) \qquad 4.62$$

where

L1ab	=	Interval value of L1 on each step
ab	=	Drop distance on each step
αmin	=	Minimum side slope angle defined by equation 4.61

The value of ab in equation 4.62 is:

$$ab = (D - D1)/2 \qquad 4.63$$

where

D	=	Digging wheel diameter to bucket cutting lips
D1	=	Digging wheel diameter without buckets (at wheel rim)

The slew angle at a distance (Y1+L1ab) is also required, see figure 4.22. this angle is defined as:

$$Sin(\psi L1ab) = (Y1 + L1ab)/[LBxCos(Khab) - E] \qquad 4.64$$

where

ψL1ab	=	Slew angle at (Y1+L1ab)

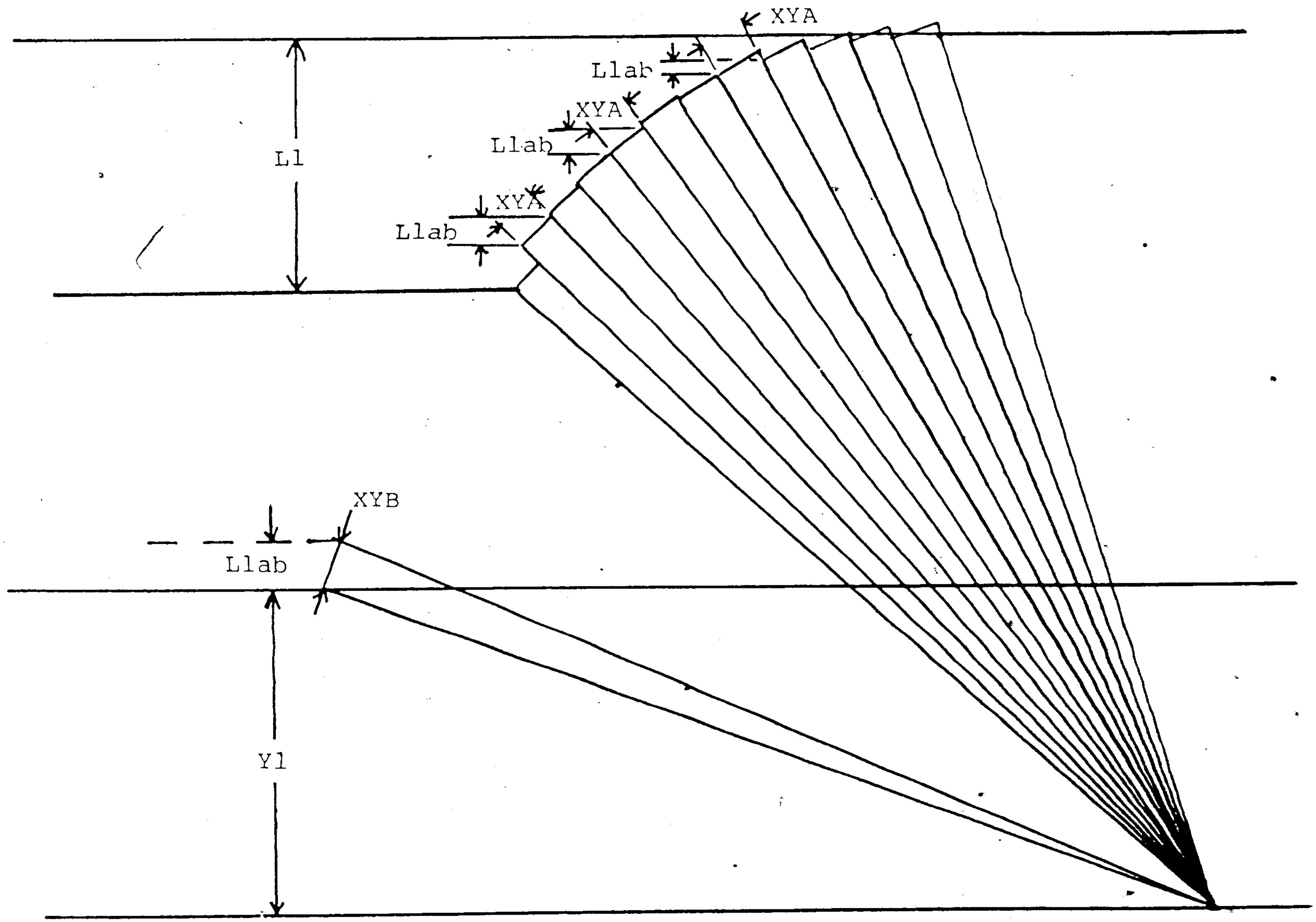


FIGURE 4.22 Determination of minimum and maximum side slope angles for Model C

Y1 = Minimum distance between the BWE centreline and toe of side slope, (defined by equation 4.44)

L1ab = Defined by equation 4.62

Khab = Load boom inclination at a height of ab above the crawler level

The length of XYB in figure 4.22 is now calculated as follows:

$$YB=[LB \times Cos(Khab)-E] \times Sin(\varphi L1ab)-Y1 \qquad 4.65a$$

$$XB=[LB \times Cos(Kd)-E] \times Cos(\varphi min)-XBB \qquad 4.65b$$

$$XBB=[LB \times Cos(Khab)-E] \times Cos(\varphi L1ab) \qquad 4.65c$$

$$XYB=((XB^2)+(YB^2))^{1/2} \qquad 4.66$$

To form the minimum side slope angle given by equation 4.61, the following must be true:

$$XYB \geqslant L2min \qquad 4.67$$

where L2min is the minimum length of line L2 for a slope height of ab; defined as:

$$L2min=ab/Tan(\alpha c) \qquad 4.68$$

where αc is the critical side slope angle (VWFA).

The maximum side slope angle that an excavator can cut is 90 degrees; however, as soon as an angle of less than 90 degrees is required, difficulties may arise.

For the maximum side slope angle, the critical length of L2min, as defined by equation 4.68, must always be applied to the curve distance, XYA, on each slice down the face, see figure 4.22. The slope distance L1ab is then calculated for each slice and added to define the total slope distance L1. It must be noted that the interval values of L1ab on each slice are calculated using an iterative method.

Once the length of L1 has been calculated, the maximum side slope angle is:

$$\tan(\alpha max)=H/(L1+RD) \qquad 4.69$$

where H and RD are as defined at the start of this section.

4.3.4 *Width of Cut*

The determination of the cut width for a dropping cut, can be done similarly to the method developed in section 4.2.4. As indicated in figure 4.23, the block width, (measured at the top of the bench), can be divided into pit side and slope side, (Wt' and Wt''), as defined by its relation to the BWE centreline of advance.

The cut width on the slope side of the BWE centreline, Wt', is defined as:

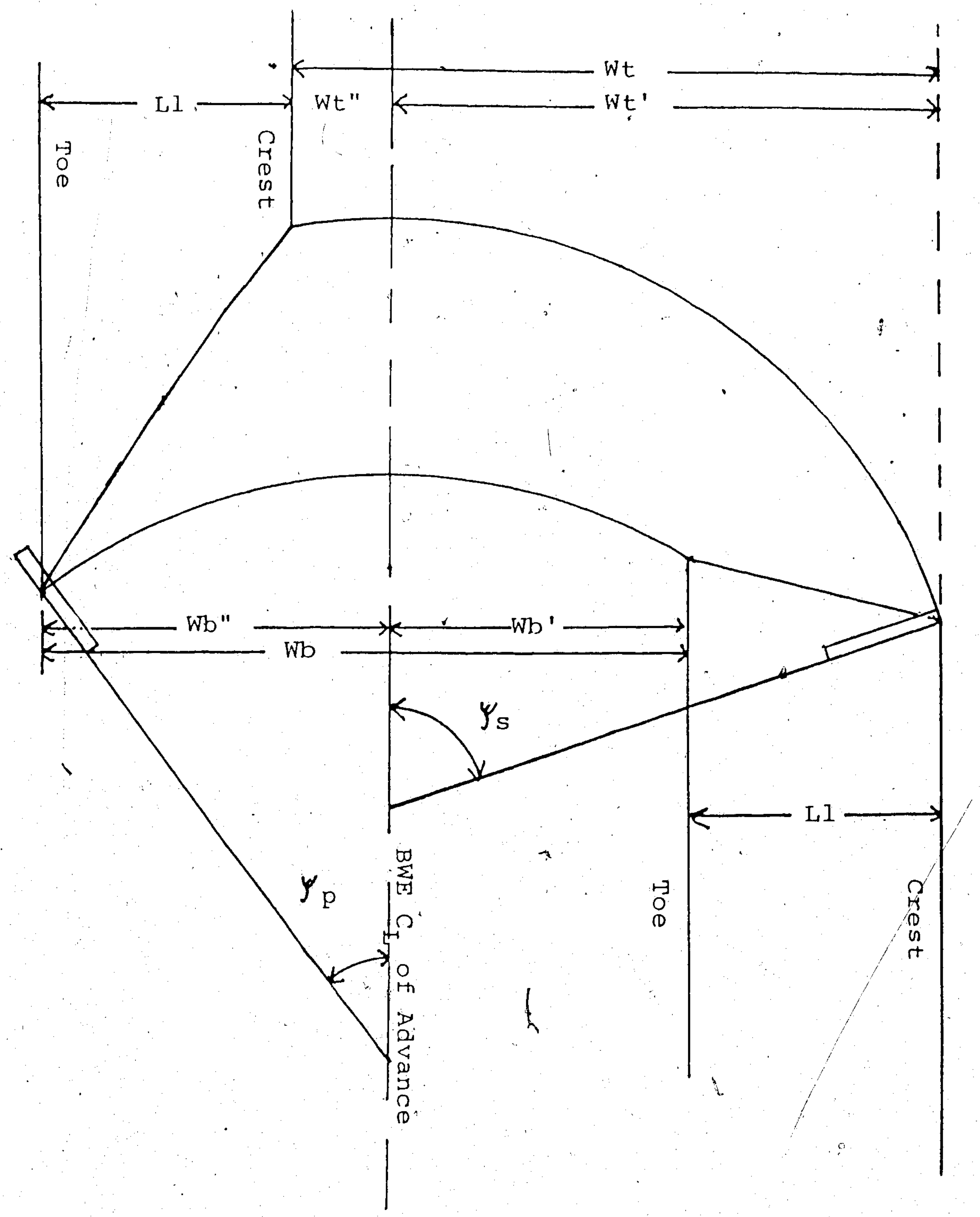


FIGURE 4.23 Width of cut using the dropping cut

$$Wt' = [LB \times Cos(Kh) - E + RD] \times Sin(\psi_s) \qquad 4.70$$

where

ψ_s = Maximum slew angle on slope side

RD = Distance between digging wheel centre and the actual slope crest

The distance RD used in equation 4.70 changes depending on the slope height and can be defined using figure 4.24.

The slope height is divided into four zones:

1/ $0 \leq H < Hs$ 4.71a

2/ $Hs \leq H < (Hs + H2)$ 4.71b

3/ $(Hs + H2) \leq H < HM$ 4.71c

4/ $H \geq HM$ 4.71d

H in the above equations is equal to the slope height, and:

$$Hs = Hdmax + ab \qquad 4.72a$$

$$H2 = R - ab - H1 \qquad 4.72b$$

$$H1 = R \times Sin(90 - \alpha) \qquad 4.72c$$

where

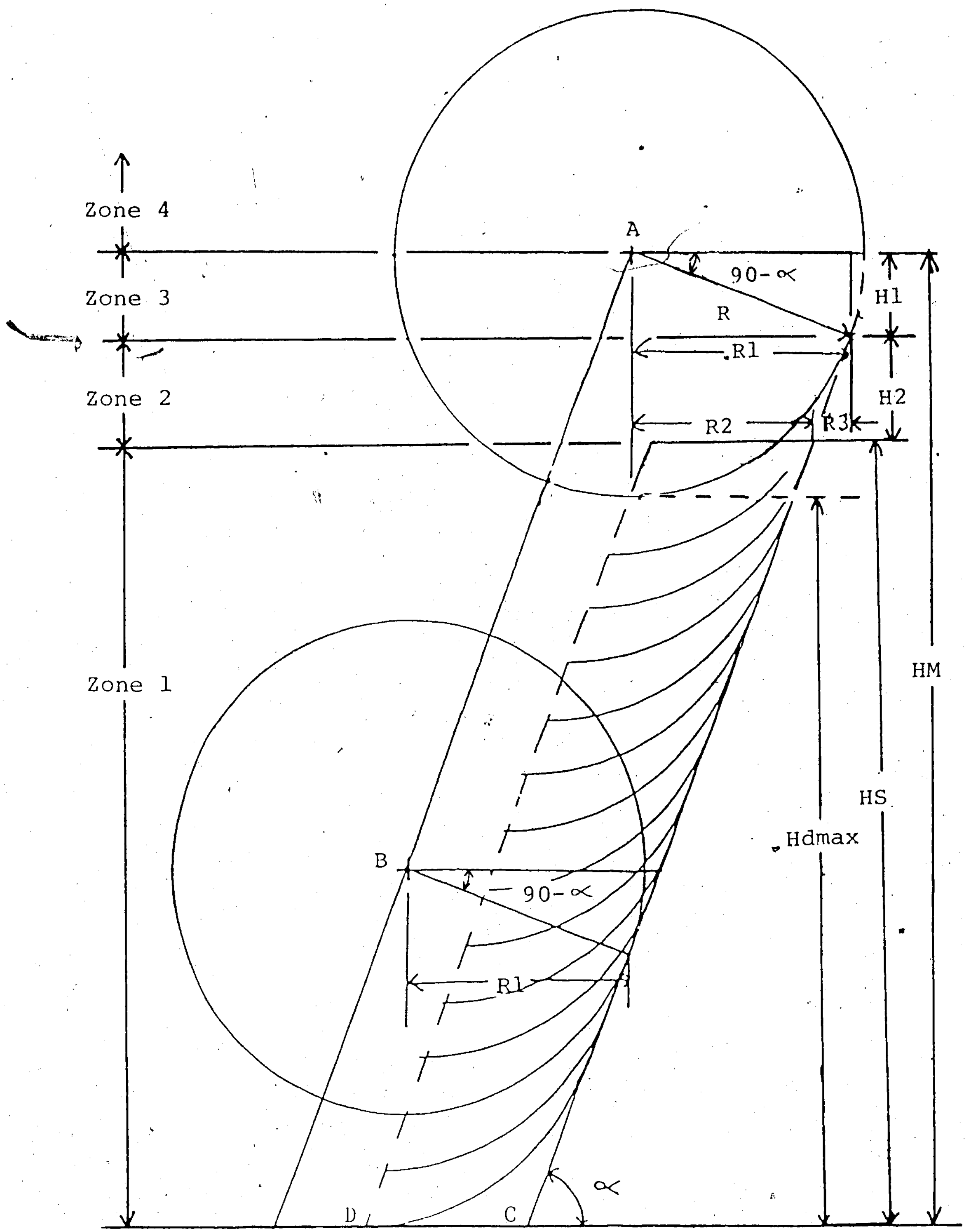


FIGURE 4.24 Determination of the actual distance between the digging wheel centre and the actual slope

Hdmax = Defined by equation 4.16

ab = Defined by equation 4.63

R = Digging wheel radius to bucket lips

α = Side slope angle

In Zone One, (defined by equation 4.71a), RD is equal to the distance R2 in figure 4.24:

$$RD=R2=R1-R3 \qquad 4.73$$

where

$$R1=R\times Cos(90-\alpha) \qquad 4.74$$

$$R3=H2/Tan(\alpha) \qquad 4.75$$

and H2 in equation 4.74 is defined by equation 4.72b. If the bench height falls in Zone Two, (as defined by equation 4.71b), the following relationship can be used to define RD:

$$RD=R1-[(H2-[H-Hs])/Tan(\alpha)] \qquad 4.76$$

where R1 is given by equation 4.74, H2 by 4.72b, and Hs by 4.72a. For a bench height in Zone Three, (as defined by equation 4.71c), RD is:

$$RD^2=R^2-(HM-H)^2 \qquad 4.77$$

In Zone Four, an over hanging slope is formed which usually breaks off. Because of this, the value of RD is assumed to be equal to the digging wheel radius, R.

The width of the cut on the pit side of the BWE centreline , Wt'', is defined as:

$$Wt''=[LB \times Cos(Kd)-E] \times Sin(\psi p)-L1 \qquad 4.78$$

where ψp is the maximum slew angle on the pit side, and:

$$L1=H/Tan(\alpha) \qquad 4.79$$

H in equation 4.79 is the slope height and α is the given side slope angle.

The total cut width for a dropping cut will be defined as:

$$Wt=Wt'+Wt'' \qquad 4.80$$

where Wt' is given by equation 4.70, and Wt'' by equation 4.78.

5.0 Computer Model Development

5.1 Introduction

In Chapter 4, relationships between the BWE design parameters and the mining slope were developed. To make these relationships readily available to potential users, computer models were developed which incorporate these relationships. These models are designed to aid the mine planning engineer by reducing the work load required to design mining slopes or select a suitable BWE. In this way, he need only concern himself with the input and output parameters, and not with the details of the relationships themselves.

This chapter gives the uses for each of the programs developed from the relationships in Chapter 4. Also provided is a flowchart showing the program development.

These programs are written in IBM Advanced Basic (BASICA) for use on the IBM personal computer (PC), and a Huston Instruments (DMP42) plotter.

As a guide to the location of each of the models developed in this section, they are listed below in order of their development within this section.

1/ *Minimum Front Slope Angle* and *Maximum Depth of Advance* as a function of Bench Height for the Terrace Cut; (see Section 5.2)

2/ *Minimum Side Slope Angle* as a function of Bench Height for the Terrace Cut;(see Section 5.3)

3/ *Width of Cut* as a function of Bench Height and Side Slope Angle for the Terrace Cut; (see Section 5.4)

4/ *Minimum Front Slope Angle* and *Maximum Depth of Advance* as a function of Bench Height for the Dropping Cut; (see Section 5.5)

5/ *Range of Side Slope Angles* as a function of Bench Height for the Dropping Cut (Model A); (see Section 5.6)

6/ *Range of Side Slope Angles* as a a function of Bench Height for the Dropping Cut (Model B); (see Section 5.7)

7/ *Range of Side Slope Angles* as a function of Bench Height for the Dropping Cut (Model C); (See Section 5.8)

8/ *Width of Cut* as a function of Bench Height and Side Slope Angle for the Dropping Cut; (see Section 5.9)

These computer models are interactive to accept the BWE design parameters from the user. The program also asks the user whether input data changes are required before exiting the program. This eliminates the need for data re-entry for multiple runs.

The models developed in this section are set up to model small compact (standard) BWEs. Large excavators are custom-tailored, and their design reflects the operation's specific needs. The standard excavator on the other hand, already has been designed (with a provision for minor design changes), and a machine must be selected to meet the operations needs. A series of tables or plots outlining the limitations of these standard machines can greatly aid in this selection process. Also, these tables or plots can be used to aid in the day to day planning of an operation already utilizing this type of excavator.

The relationships developed in Chapter Four are a function of bench height, and some other parameter which must be given. The programs use pre-set values for each of these required parameters. Although the computer models were developed specifically for compact BWEs, they can be easily modified to accommodate any size of machine.

5.2 Minimum Front Slope Angle and Maximum Advance of an Excavator in the Terrace Cut

5.2.1 *Introduction and Model Uses*

The relationships used for this model may be found in Section 4.2.2; the specific equations used are 4.7, 4.8 and 4.9. This program is used to determine the following limitations.

1/ Minimum front slope angle as a function of bench height and excavator advance

2/ Maximum excavator advance as a function of bench height and front slope angle

The output from these two relations provide the same information; however, it is easier to use one, or the other depending on the limit being determined.

The primary purpose of both types of output is to:

i Determine if a particular BWE is capable of forming the required front slope angle and advance for a given bench height

However, there are also several secondary uses, as listed below:

ii Find the minimum front slope angle, given the bench height, and required excavator advance

iii Find the maximum advance, given the bench height and required front slope angle

iv Find the maximum bench height, given the front slope angle, and required excavator advance

A listing of the program is provided in Appendix I-1 along with a sample run. Appendix II-1 shows sample output in both table and graph form. The flowchart used to develop this program is shown in figure 5.1.

5.3 Minimum Side Slope Angle for the Terrace Cut

5.3.1 *Introduction and Model Uses*

The minimum side slope angle depends on the BWE design parameters, bench height, and the minimum slew angle. The relationship used in this model is given by equation 4.12 in Section 4.2.3.

The output produced, relating minimum side slope angle and the bench height, can be used in several ways. The primary use is to:

i Determine if a particular BWE can form the required side slope angle given a required bench height

This output also permits the following limits to be determined:

ii Find the minimum side slope angle, given the bench height and the maximum slew angle, (φ_s)

iii Determine the bench height for a particular side slope angle and maximum slew angle, (φ_s)

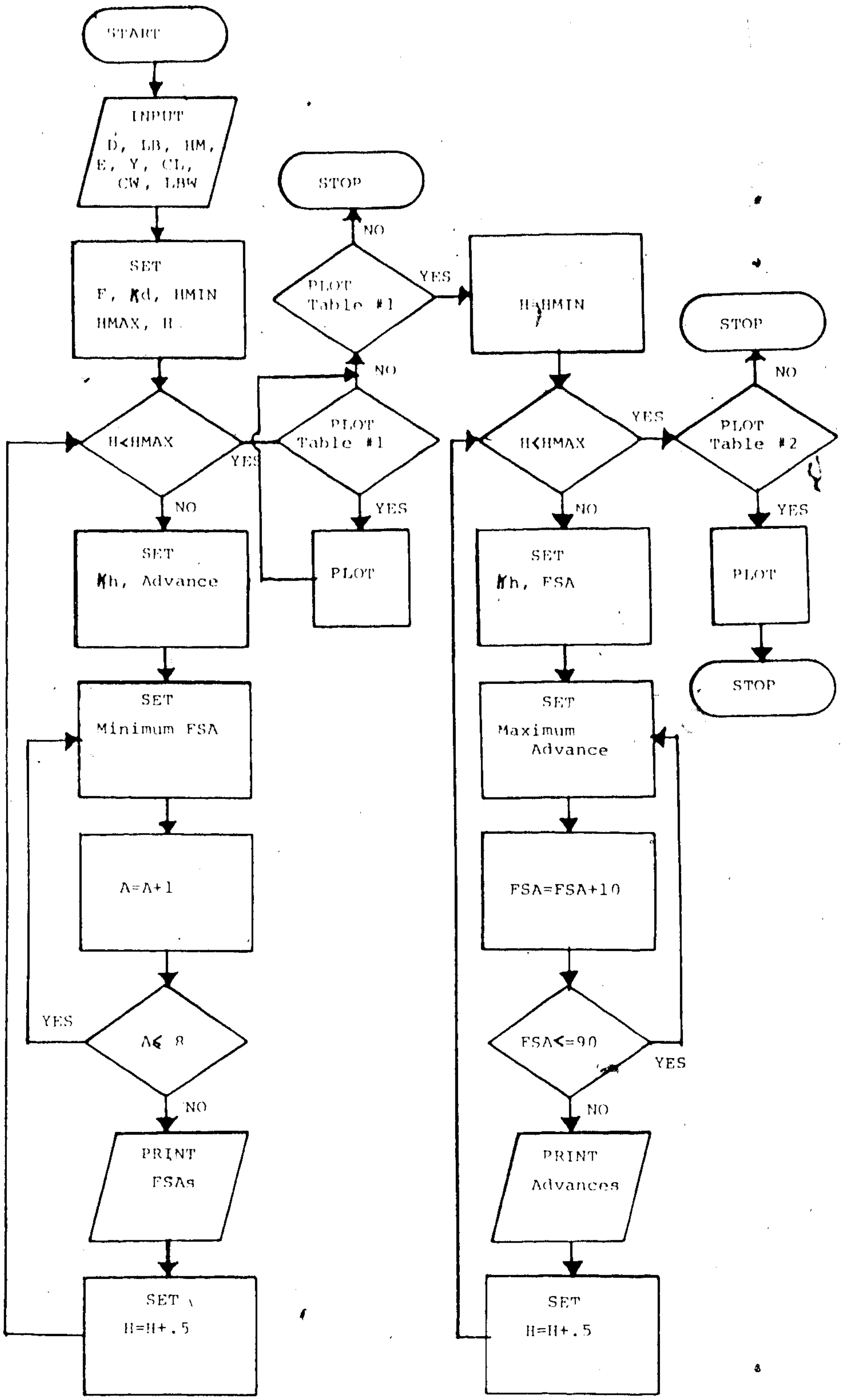


FIGURE 5.1 Flowchart showing the determination of the minimum front slope angle and maximum advance for a terrace cut

iv Determine the range of maximum slew angles, (ψs), required, for a given bench height and side slope angle

The relationships given above are dependent on the minimum slew angles, and they change accordingly.

A listing of the program can be found in Appendix I-2 together with a sample run. Appendix II-2 shows sample output in both table and graph form. Figure 5.2 shows the flowchart used to develop this program.

5.4 Width of Cut for the Terrace Cut

5.4.1 *Introduction and Model Uses*

One of the most important slope design considerations is the cut width. It is this relationship that influences conveyor moves, productivity and the overall mine design.

The width of a cut depends on the slope height, side slope angle, the maximum slope side and pit side slew angles, and the BWE design parameters. The relationship used to develop this model is given by equation 4.18 in Section 4.2.4.

The program developed in this section allows the operator to analyse the results of design changes, simply by changing the program input variables.

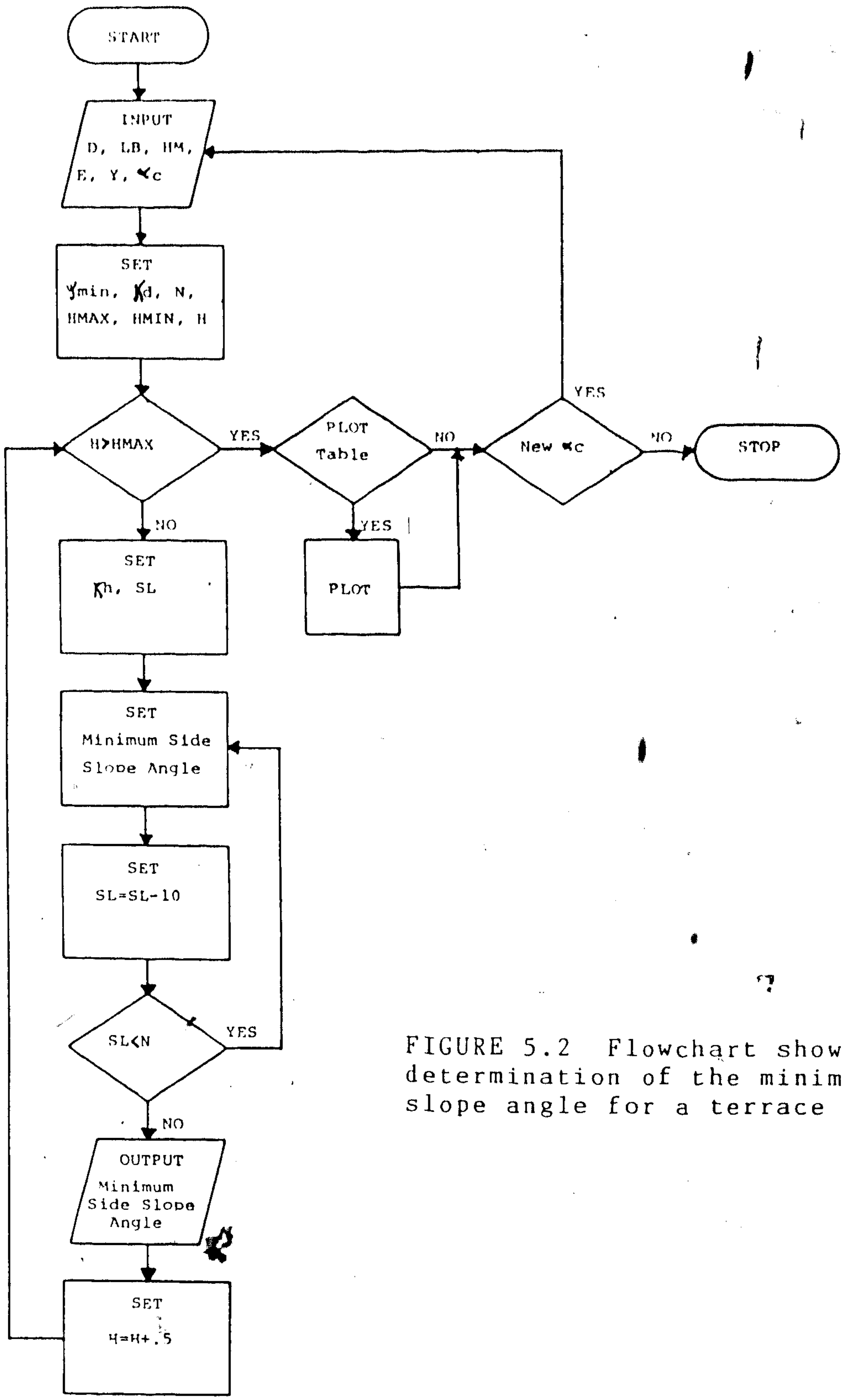


FIGURE 5.2 Flowchart showing the determination of the minimum side slope angle for a terrace cut

The output obtained from the this program can be used in several ways. The primary use is:

i Determine if a particular BWE is capable of forming the required bench height, cut width, and side slope angle

There are also several secondary uses for the output as listed below:

ii Find the possible combinations of the maximum slew angles, (ψ_s and ψ_p), for a given bench height required side slope angle, and desired cut width

iii Define the width of a cut, given the bench height required side slope angle, and the maximum slew angles, (ψ_s and ψ_p)

iv Define the required pit side slew angle, (ψ_p), given the bench height, required side slope angle, cut width desired, and the maximum slew angle on the slope side, (ψ_s)

v Define the required side slope slew angle, (ψ_s), given the bench height, required side slope angle, cut width desired, and the pit side slew angle, (ψ_p)

vi Find the minimum side slope angle, given the bench height, cut width desired, and the maximum slew angles, (ψ_s and ψ_p)

vii Find the maximum bench height, given the desired cut width, required side slope angle, and the maximum slew angles, (ψ_s and ψ_p)

A listing of the program can be found in Appendix I-3, along with a sample run. Appendix II-3 gives sample output in both table and graph form. Figure 5.3 shows the flowchart used to develop this program.

5.5 Minimum Front Slope Angle and Maximum Advance for the Dropping Cut

5.5.1 *Introduction and Model Uses*

This program contains two relationships:

1/ Minimum front slope angle as a function of bench height and given advance

2/ Maximum advance as a function of bench height and given front slope angle

The relationships used to develop this model are given by equations 4.21, 4.23, and 4.24 in Section 4.3.2

The output from these two relationships provide the same information and can be used in several different ways. The primary purpose of both sets of output is to:

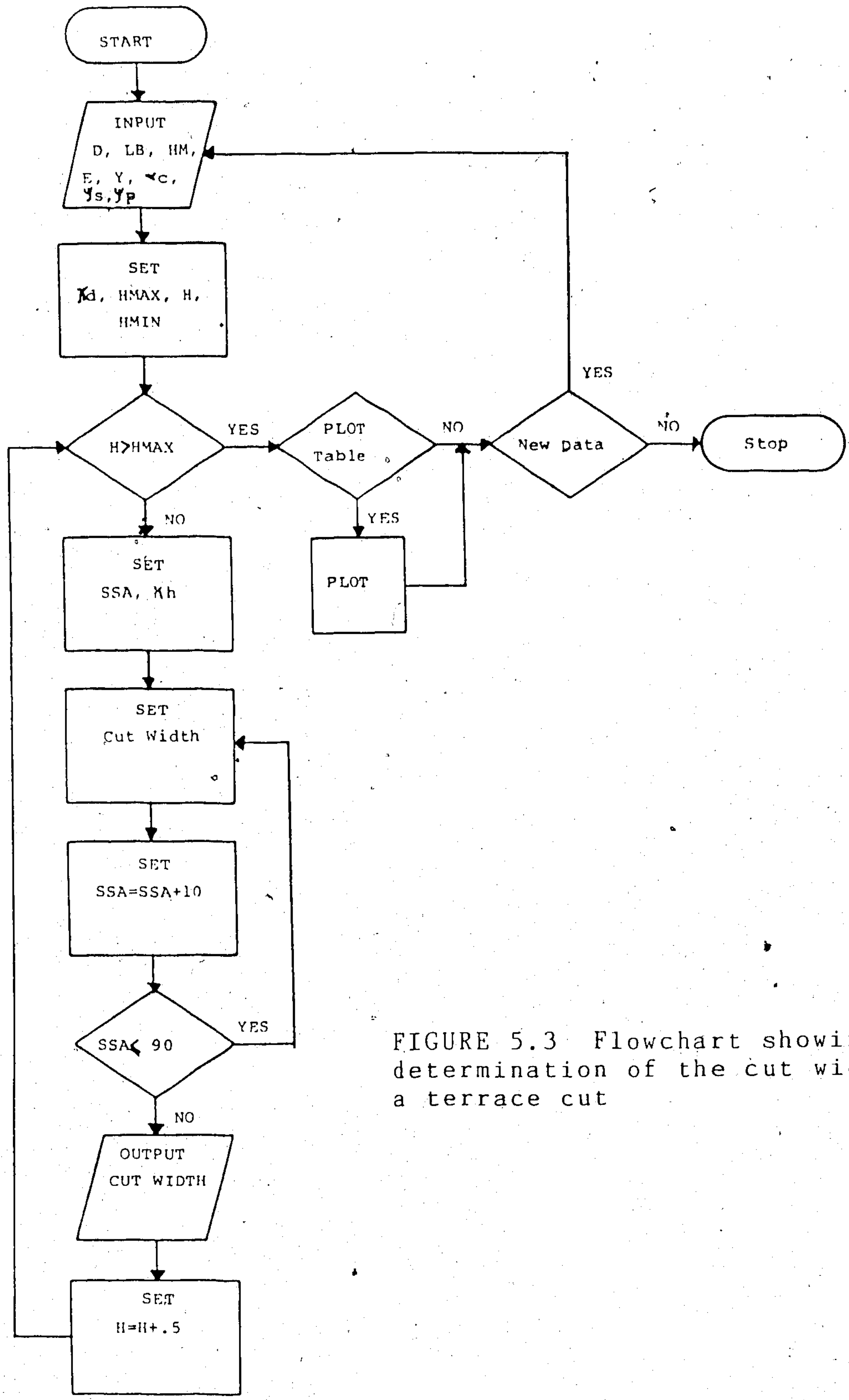


FIGURE 5.3 Flowchart showing the determination of the cut width for a terrace cut

i Determine if a particular BWE is capable of forming the required front slope angle and advance for a given bench height

Secondary uses for this output are:

ii Find the minimum front slope angle, given the bench height and required depth of advance

iii Find the maximum depth of advance, given the bench height and required front slope angle

iv Find the maximum bench height, given the required front slope angle and advance

Although both sets of output can be used determine each of these limits, it is easier to use one, or the other, depending which limit is being determined.

A listing of the program can be found in Appendix I-4 along with a sample run. Appendix II-4 shows sample output in both table and graph form. Figure 5.4 shows the flowchart used to to develop this program.

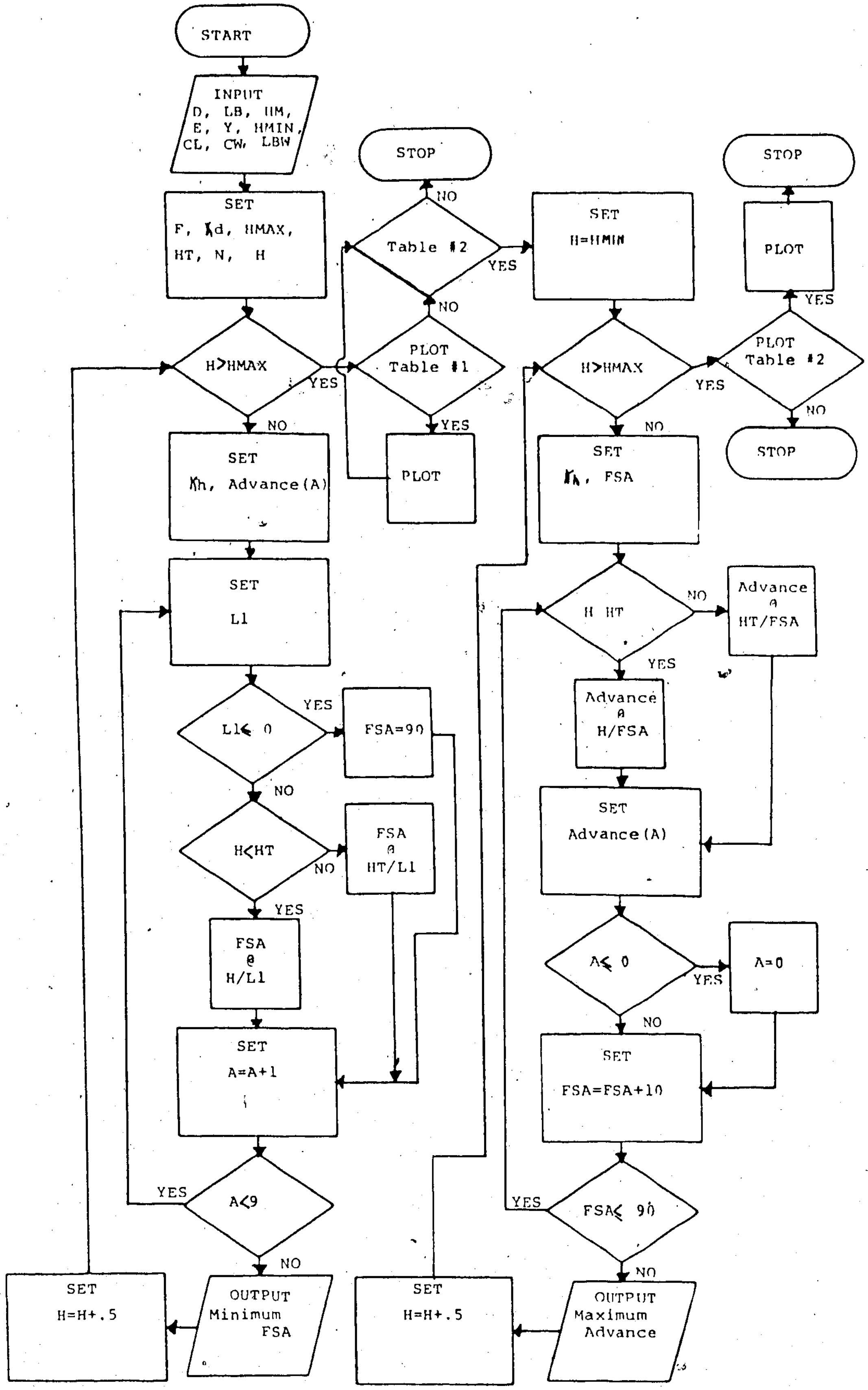


FIGURE 5.4 Flowchart showing the determination of the minimum front slope angle and the maximum advance for a dropping cut

5.6 Range of Side Slope Angles for the Dropping Cut (Model A)

5.6.1 *Introduction and Model Uses*

The major problem in designing a dropping cut is the determination of the side slope angle. The relationships involved are complex and require making some assumptions. The program developed in this section uses the assumption outlined in Section 4.3.3 (Model A).

The output from the program developed using the relationships from Section 4.3.3 (Model A), can be used in several ways. The primary use is to:

i Determine if the particular BWE is capable of forming the side slope, given a bench height, maximum slew angle, (Ψs), and the front slope angle

The output can also be used to:

ii Find the range of side slope angles possible for a given bench height, the maximum slew angle, (Ψs), and required front slope angle iii Find the range of maximum slew angles, (ψs), given the bench height, the required side slope angle, and required front slope angle

iv Find the range of front slope angles which can be used, given the bench height, maximum slew angle, (ψs), and the required side slope angle

v Find the maximum bench height, given the required side slope angle, maximum slew angle, (ψs), and the front slope angle required

In the above uses, the maximum slew angle, ψs, cannot be less than the minimum slew angle calculated for an excavator.

This model does not describe the side slope well and was rejected. Because of this the program listing and output are not provided. Figures 5.5a and 5.5b show the flowchart used for this program.

5.7 Range of Side Slope Angles for the Dropping Cut (Model B)

5.7.1 *Introduction and Model Uses*

Model B employs a different assumption for developing the side slope angle range than is used for Model A. The

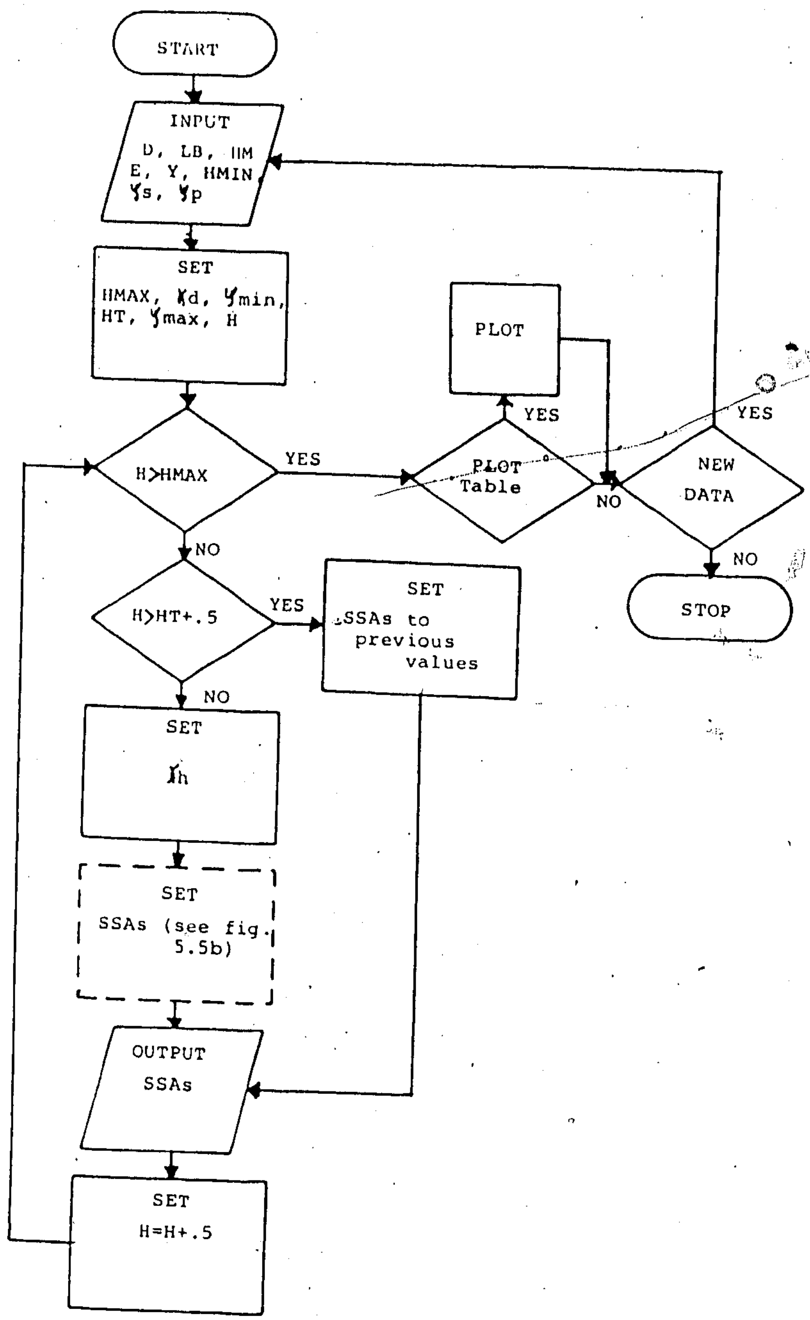


FIGURE 5.5a Flowchart showing the determination of the side slope angle range for Model A

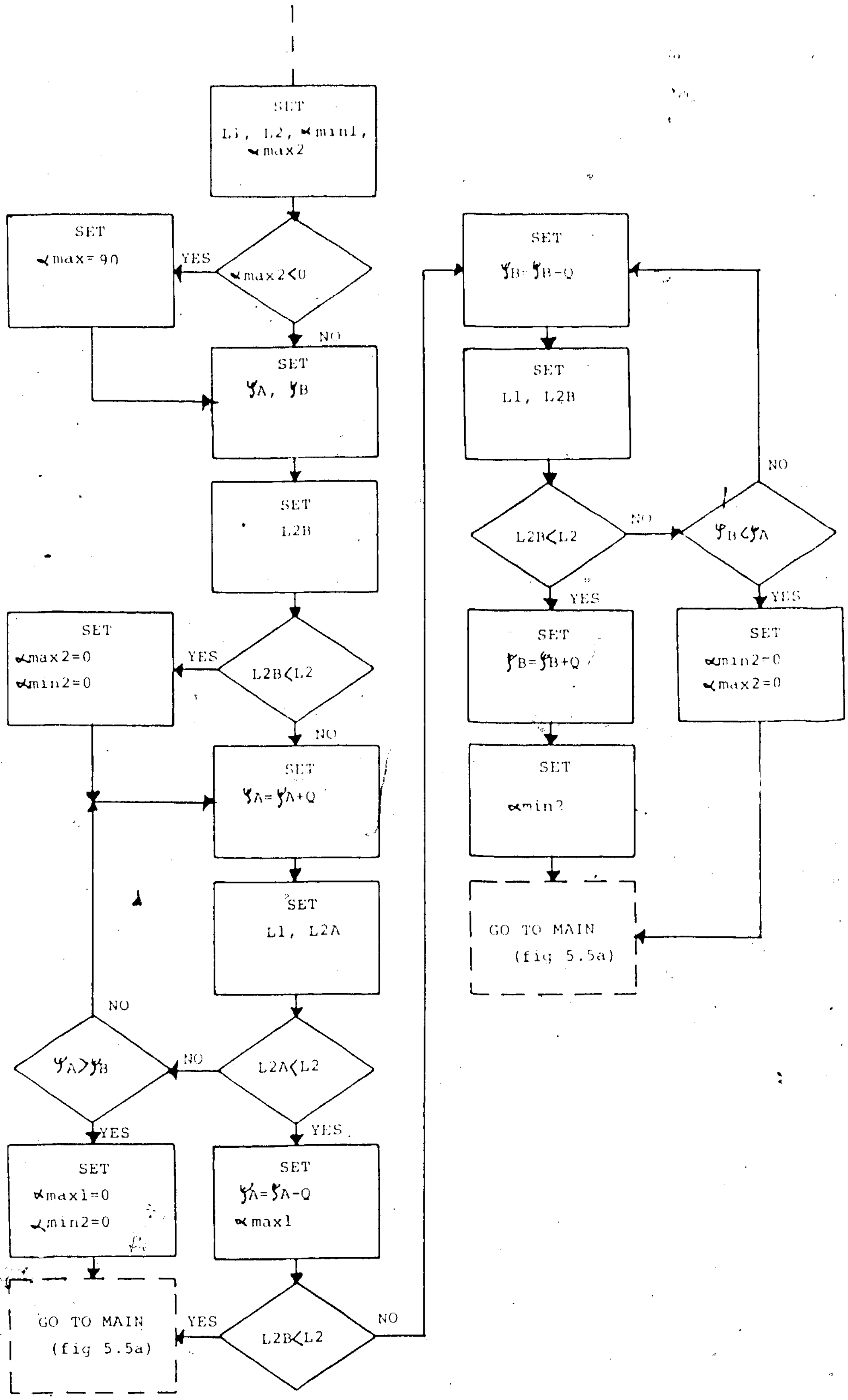


FIGURE 5.5b Flowchart showing the determination of the side slope angle range for Model A (cont)

program developed in this section used the assumption outlined in Section 4.3.3, (Model B).

The output developed using this model can be used in several ways. The primary use is to:

i Determine if the given BWE is capable of forming the side slope, given a bench height and maximum slew angle, (ψs)

The secondary uses of the output are:

ii Find the range of side slope angles possible, for a given the bench height, and maximum slew angle, (ψs)

iii Find the range of maximum slew angles, (ψs), given the bench height, and the required side slope angle

iv Find the maximum bench height, given the maximum slew angle, (ψs), and the required side slope angle

The maximum slew angle, ψs, cannot be less than the minimum slew angle calculated for a particular excavator.

A listing of the program and sample output for Model B is not provided because it does not describe the slope well. The flowchart used to develop this program is shown in figures 5.6a and 5.6b.

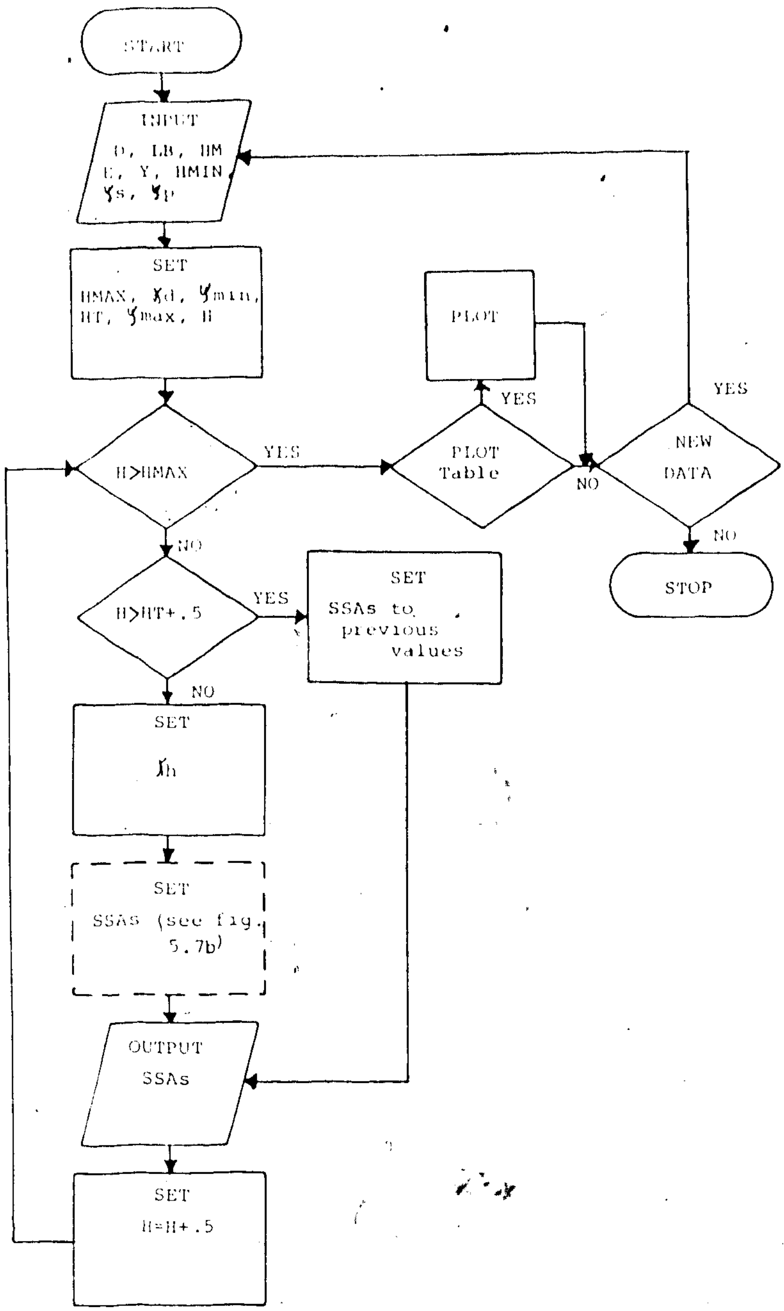


FIGURE 5.6a Flowchart showing the determination of the side slope angle range for Model B

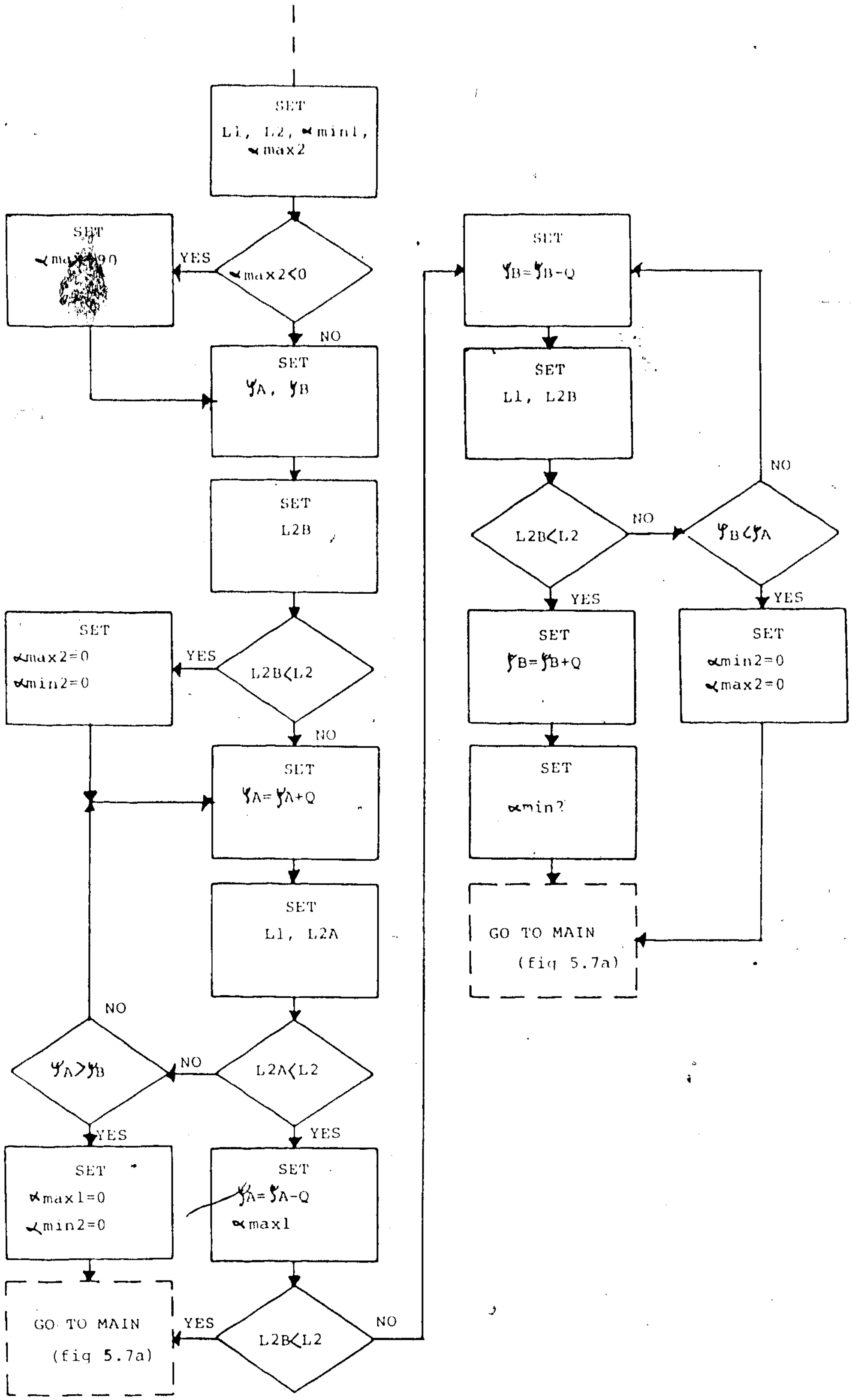


FIGURE 5.6b Flowchart showing the determination of the side slope angle range for Model B (cont)

5.8 Range of Side Slope Angles for the Dropping Cut (Model C)

5.8.1 *Introduction and Model Uses*

Model C uses the actual slope to determine the side slope angle range rather than the digging wheel centre. This method was suggested by SECV (Rodgers, 1971, 1976) and is outlined in Section 4.3.3, (Model C).

The primary use of the output developed from this model is:

i Determine if the given BWE is capable of forming the side slope, given a bench height, and maximum slew angle, (ψ_s)

The secondary uses of the output are:

ii Find the range of side slope angles possible for a given bench height, and maximum slew angle, (ψ_s)

iii Find the range of maximum slew angles, (ψ_s), given the bench height and the required side slope angle

iv Find the maximum bench height, given the maximum slew angle, (ψ_s), and the required side slope angle

In the above, the maximum slew angle, ψ_s, cannot be less than the minimum slew angle calculated for a given excavator.

A listing of the program and a sample run can be found in Appendix I-5. Appendix II-5 show sample output in both table and graph form. Figure 5.7 show the flowchart used to develop this program.

5.9 Width of Cut for the Dropping Cut

5.9.1 *Introduction and Model Uses*

Factors that influence the cut width are slope height, side slope angle, maximum pit side and slope side slew angles, and the BWE design parameters. The relationship used to develop this model is given by equation 4.80 in Section 4.3.4.

The program developed in this section allows the operator to change the slew angles, or the VWFA to analyse the results these changes make on the output.

The output that has been developed for the dropping cut width can be used in several ways. The primary use is to:

i Determine if the particular BWE is capable of forming given bench height, desired cut width, and required side slope angle

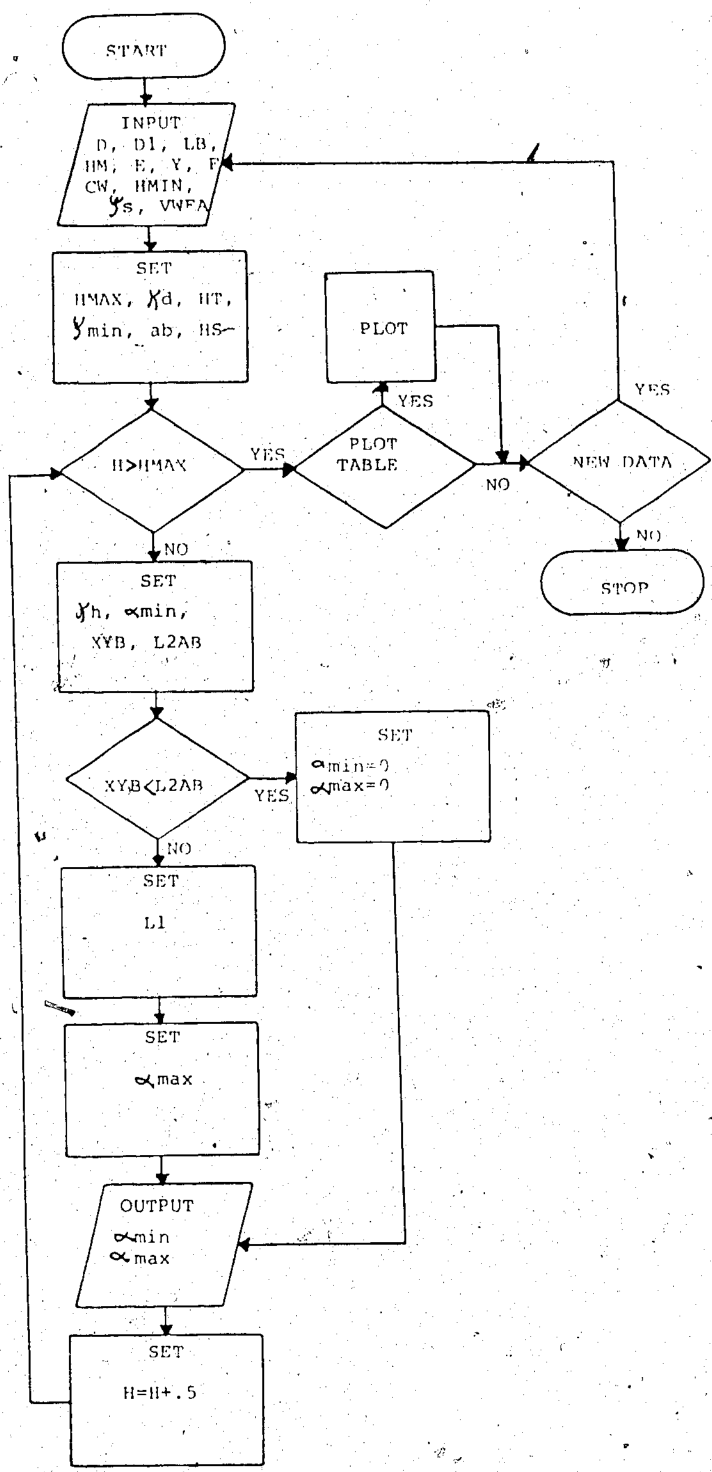


FIGURE 5.7 Flowchart showing the determination of the side slope angle range for Model C

The secondary uses of the output are:

ii Find the possible combinations of the maximum slew angles, (ψs and ψp), for a given bench height, required side slope angle and desired cut width

iii Define the width of a cut, given the bench height, required side slope angle, and the maximum slew angles (ψs and ψp)

iv Define the required pit side slew angle, (ψp), given the bench height, required side slope angle, cut width desired, and the maximum slew angle on the slope side, (ψs)

v Define the required side slope slew angle, (ψs), given the bench height, required side slope angle, cut width desired, and the pit side slew angle, (ψp)

vi Find the minimum side slope angle, given the bench height, cut width desired, and the maximum slew angles, (ψs and ψp)

vii Find the maximum bench height, given the desired cut width, required side slope angle, and the maximum slew angles, (ψs and ψn)

A listing of the program is located in Appendix I-6 along with a sample run. Sample output in both table and graph form is provided in Appendix II-6. Figure 5.8 shows the flowchart used to develop this program.

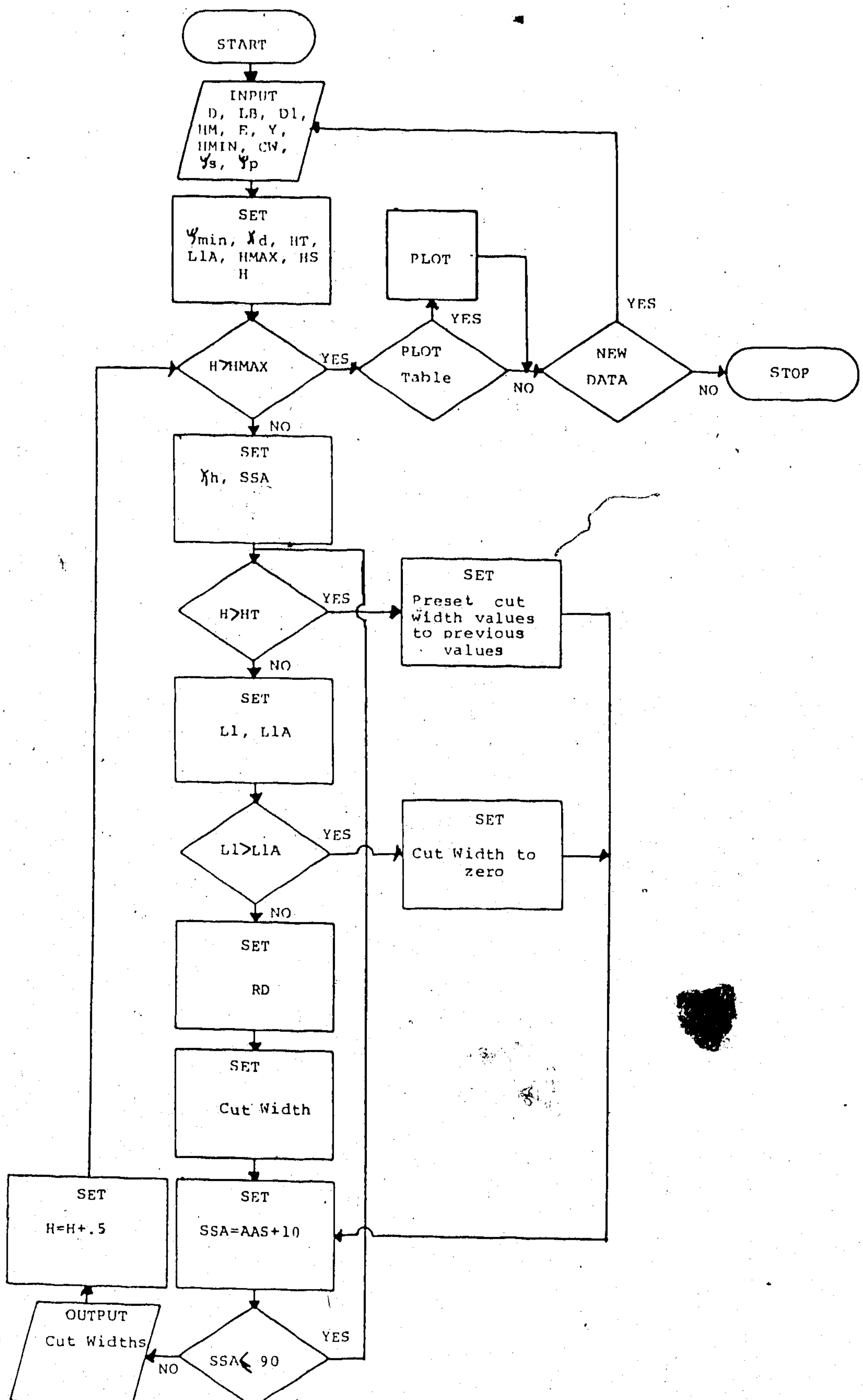


FIGURE 5.8 Flowchart showing the determination of the cut with using a dropping cut

6.0 Physical Model Development

6.1 Introduction

The relatonships developed in Chapter 4 were determined using the geometry between the excavator and the mining slopes. Because of this, their correctness needed to be tested. This was done using a scaled-down model of the O&K SH 630 compact BWE. In this way, the actual mining slope was simulated. The O&K SH 630 was selected, because it represents the size best suited to conditions in Western Canada and the Western United States, (see Section 2.5). Also, the manufacturer was helpful in supplying the dimensions required for the construction of the scale model.

6.2 Scale Model

To test the results of the analytical models, a scale replica of an O&K SH 630 BWE was constructed. A scale of 1:50 was selected, because it represented the most convenient size to work with, while still giving reasonably detailed model slopes.

The model is built of wood with a slewable superstructure, vertically adjustable load boom, and a digging wheel, (with a cutting edge representing the buckets). The whole model is mounted on a base, which allows movement in the direction of the line of advance, but not perpendicular to it. The model is shown in figures 6-1 and 6-2.

6.3 Selection on Model Slopes

6.3.1 *Terrace Cut*

Because of the simplicity of the relations developed for the terrace cut, one slope model is considered to be sufficient to confirm the results obtained from the program based on these relationships. The slope, (Model T1), confirms all relationships developed for the terrace cut design.

Model T1

FSA	70 degrees
SSA	60 degrees
ψ_s	80 degrees
ψ_p	30 degrees
Advance	5.2 meters
Height	13 meters
Cut Width	18.8 meters

The output used to select this model is shown in figures 6.1 to 6.4.

FSA = 70 degrees represents a good average for slopes staying open for short periods of time

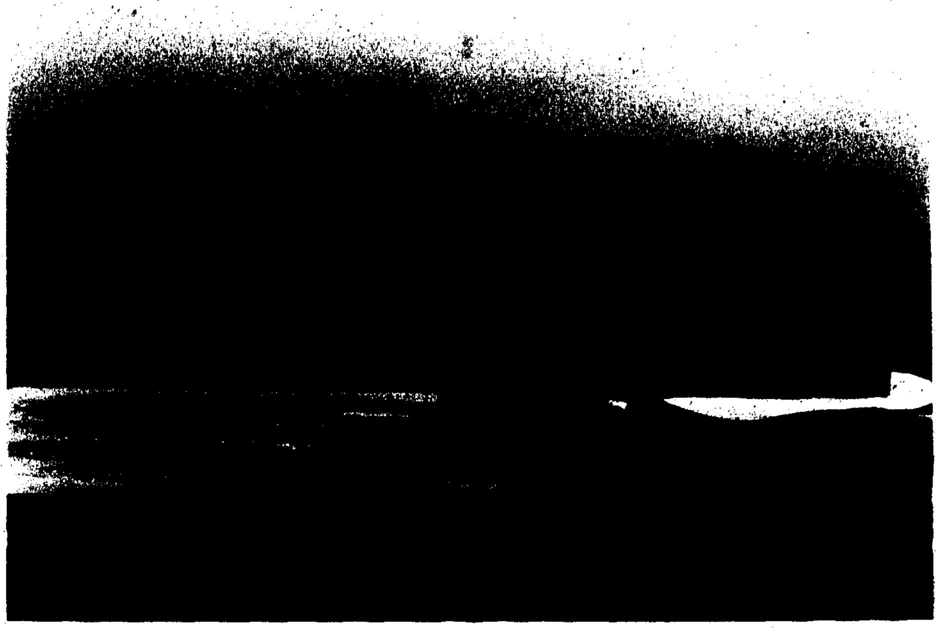


FIGURE 6-1; Model of SH 630, (view from side)

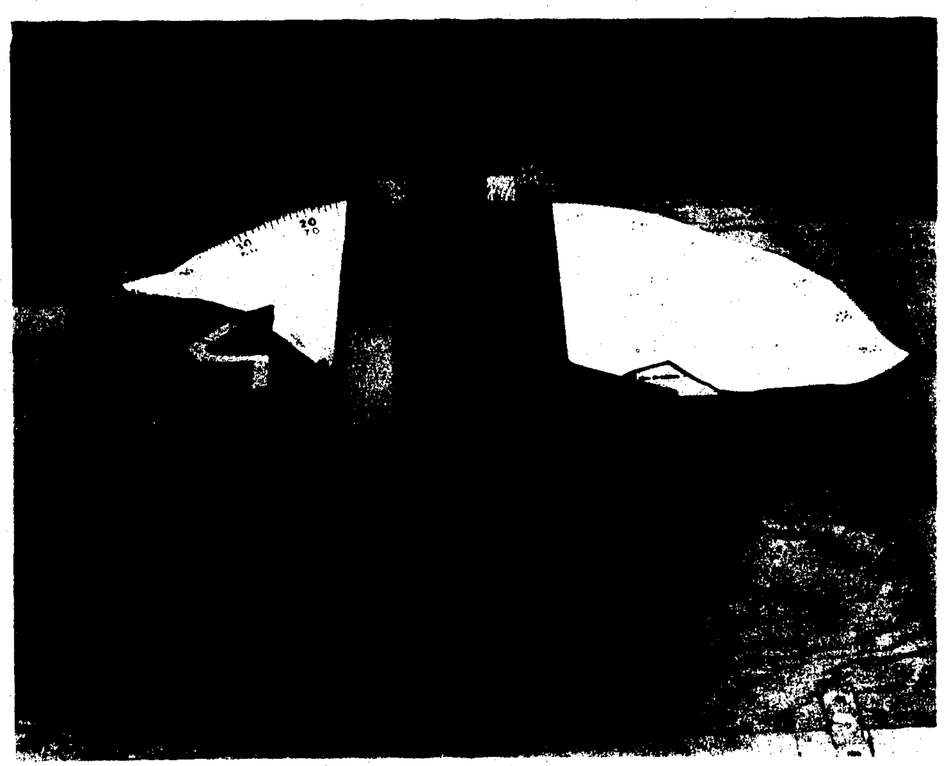


FIGURE 6-2; Model of SH 630, (view from top)

SSA = A slope of 60 degrees is well within the range of typical side slopes for benches of 13 meters

φ_s = 80 degrees is the slew angle recomended to keep productivity at acceptable levels

φ_p = A pit side slew angle of 30 degrees is considered to be reasonable for the terrace cut

Advance = Maximum advance the excavator can make, given a front slope angle of 70 degrees, and a bench height of 12.6 meters

Height = A slope height of 13 meters demonstrates that the terraces do not have to be equal, (in this case, the top terrace is 0.55 times the digging wheel diameter, while the other two terraces are 0.5 times the digging wheel diameter)

Cut Width = Width of cut expected, using maximum slew angles of 80 degrees on the slope side, and 30 degrees on the pit side at a bench height of 12.6 meters

Appendix III shows a listing of the slew angles and front slope distances used to construct this slope.

MINIMUM OVERALL FRONT SLOPE ANGLE AS A FUNCTION OF HEIGHT FOR THE TERRACE CUT

O&K SH 630

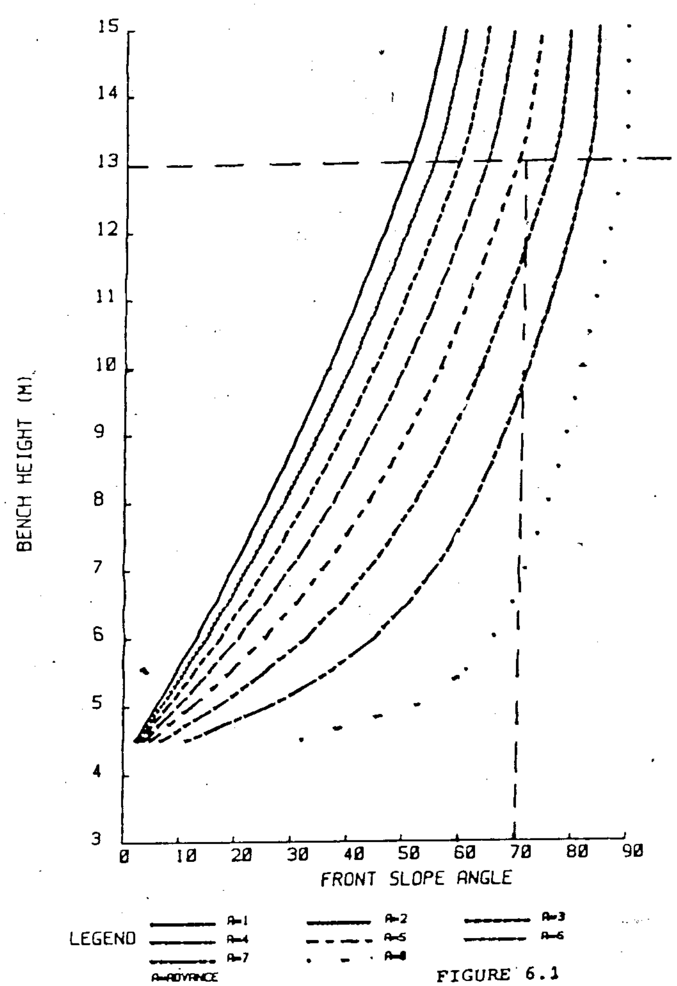


FIGURE 6.1

MAXIMUM ADVANCE AS A FUNCTION OF HEIGHT FOR THE TERRACE CUT

O&K SH 630

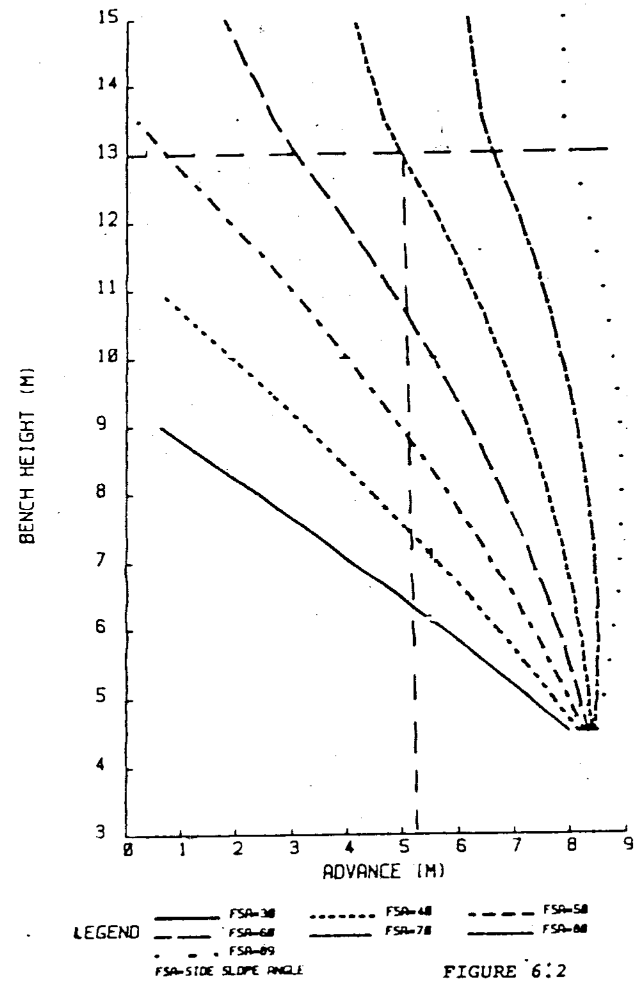


FIGURE 6.2

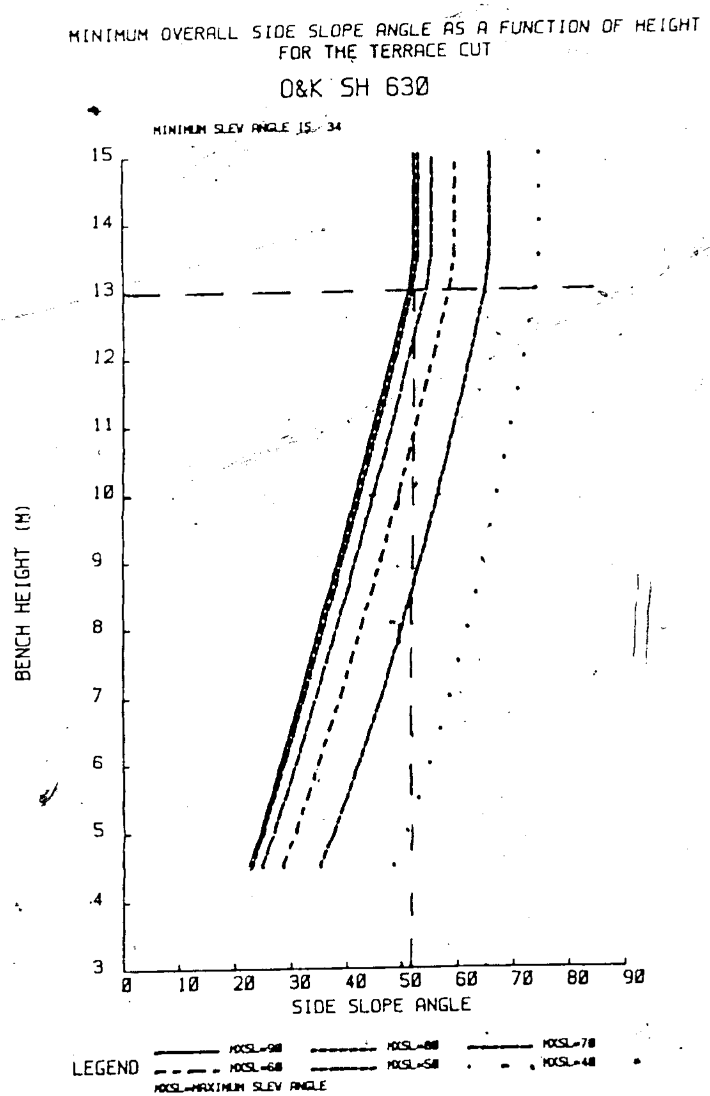


FIGURE 6.3

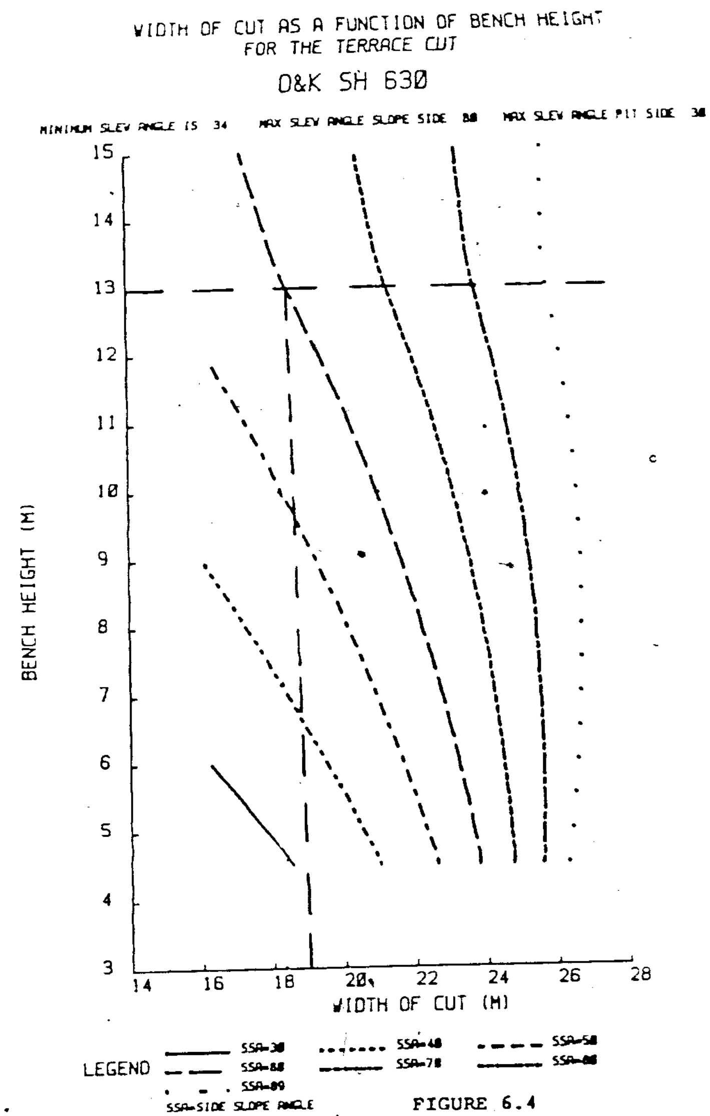


FIGURE 6.4

6.3.2 *Dropping Cut*

For the dropping cut, the relationships to be tested are:

1/ Front slope angle, as a function of bench height and excavator advance

2/ Maximum advance, as a function of bench height and front slope angle

3/ Side slope angle, as a function of bench height

4/ Cut width, as a function of bench height and side slope angle

Special consideration must be given to the side slope angle because its relationship requires several design models to be tested.

To test the accuracy of all the relationships, (except the side slope angle), the following slope was constructed:

Model D1

FSA	60 degrees
SSA	60 degrees
ψs	70 degrees
ψp	30 degrees
Advance	2.75 meters
Height	10 meters
Cut Width	18 meters

The output used to select this model is given in figures 6.5, 6.6 and 6.7.

FSA	=	A front slope angle of 60 degrees represents a good average for slopes staying open open for short periods
SSA	=	Selected at 60 degrees; all models used to determine the side slope angle confirm a side slope of 60 degrees can be formed
Ψ_s	=	Selected at 70 degrees to keep productivity at acceptable levels
Ψ_p	=	30 degrees is a reasonable slew angle on the pit side
Advance	=	Maximum advance the excavator can make, given a front slope angle of 60 degrees
Height	=	Selected as 10 meters to simplify modeling of the slopes
Cut Width	=	Width of cut expected, using a slew angle of 70 degrees on the slope side, and 30 degrees on the pit side

To select the side slope angle relationship which best describes the side slope, each of the three models developed had to be tested. A series of slopes for each model was selected, such that the model would either be confirmed, or rejected.

The assumption used in Model A, gives a possible range of side slope angles represented by:

MINIMUM OVERALL FRONT SLOPE ANGLE AS A FUNCTION OF HEIGHT
FOR THE DROPPING CUT

O&K SH 630

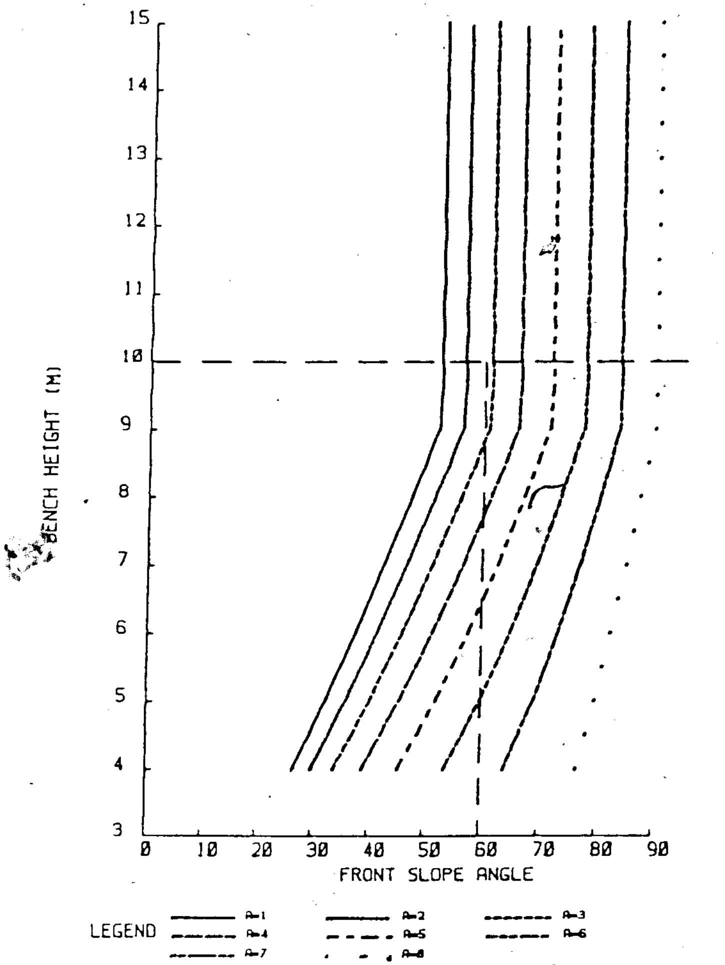


FIGURE 6.5

MAXIMUM ADVANCE AS A FUNCTION OF HEIGHT
FOR THE DROPPING CUT

O&K SH 630

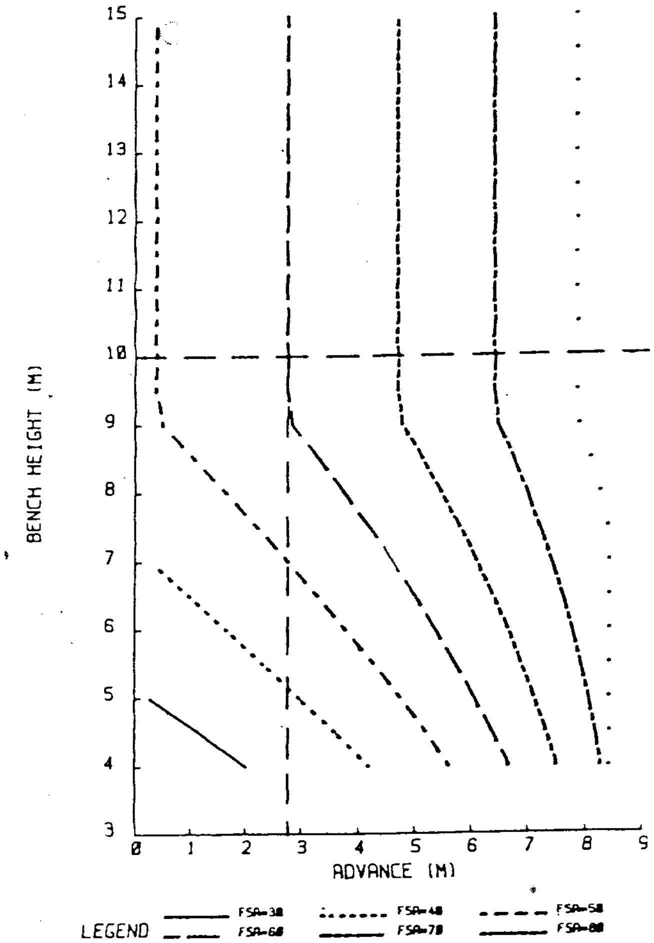


FIGURE 6.6

VIDTH OF CUT AS A FUNCTION OF BENCH HEIGHT
FOR THE DROPPING CUT
O&K SH 630

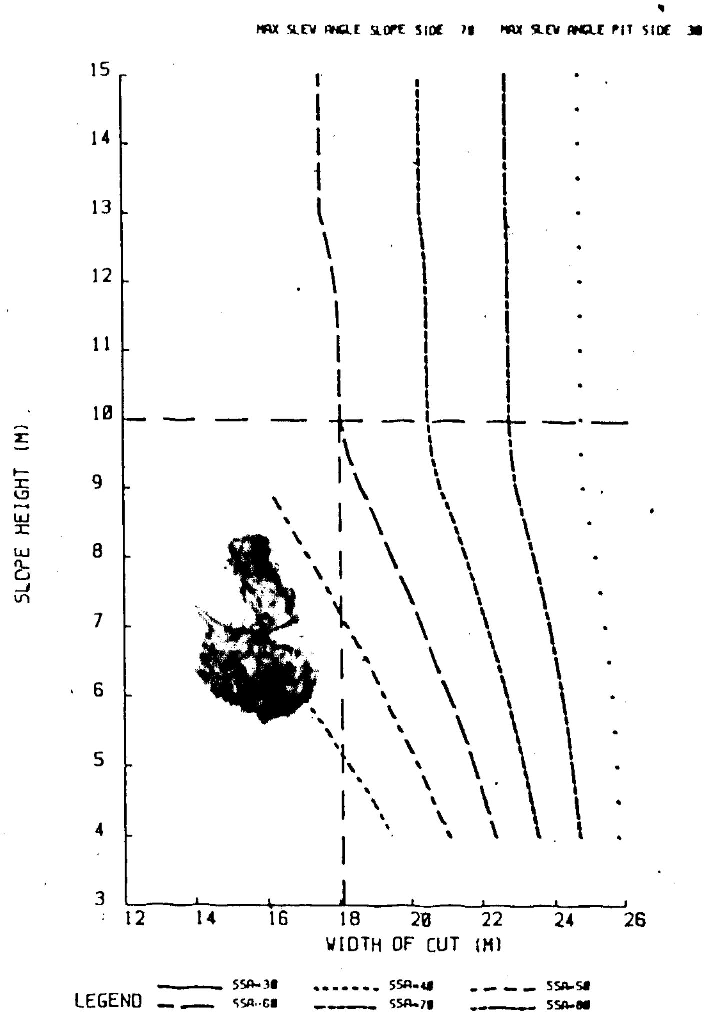


FIGURE 6.7

$$\alpha_{min1} \leq \alpha \leq \alpha_{max1} \text{ and } \alpha_{min2} \leq \alpha \leq \alpha_{max2} \qquad 6.1$$

Within this range, the side slope can fall into one of three zones defined as:

1/ $\alpha_{min1} \leq \alpha \leq \alpha_{max1}$ 6.2a

2/ $\alpha_{max1} \leq \alpha < \alpha_{min2}$ 6.2b

3/ $\alpha_{min2} \leq \alpha \leq \alpha_{max2}$ 6.2c

To confirm or reject this model, the side slope angles must be selected to fall into each of these three zones. Based on figure 6.8, the selected slopes are:

Model D2-A

FSA	45 degrees
SSA	60 degrees
ψ_s	70 degrees
Advance	2.5 meters
Height	10 meters

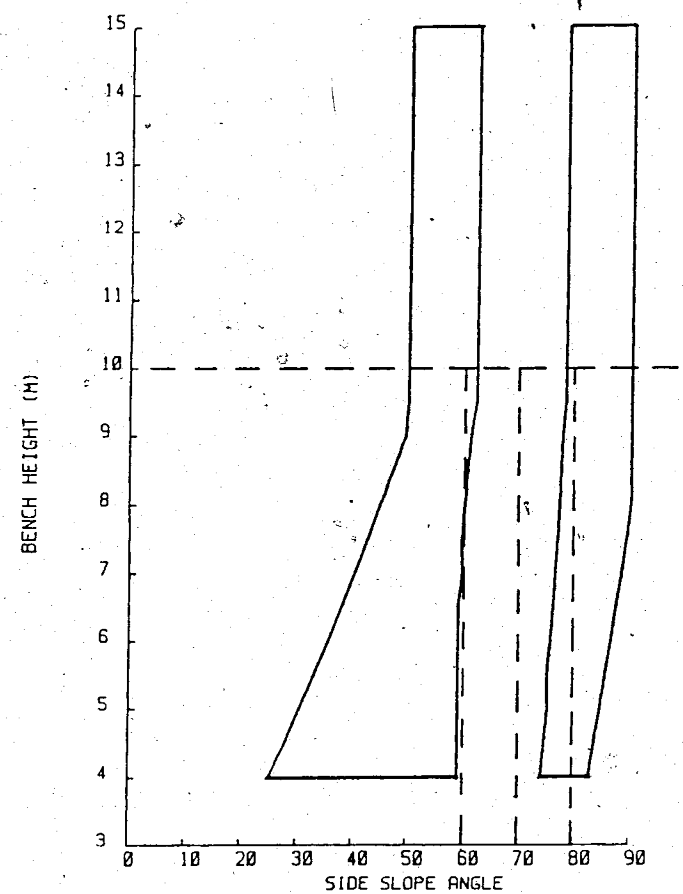
Model D3-A

FSA	45 degrees
SSA	70 degrees
ψ_s	70 degrees
Advance	2.5 meters
Height	10 meters

RANGE OF SIDE SLOPE ANGLES AS A FUNCTION OF HEIGHT AND FRONT SLOPE ANGLE FOR THE DROPPING CUT (MODEL A)

O&K SH 630

FRONT SLOPE ANGLE 45 MAX SLEV ANGLE SLOPE SIDE 70 VERTICAL WHEEL FREE ANGLE 59



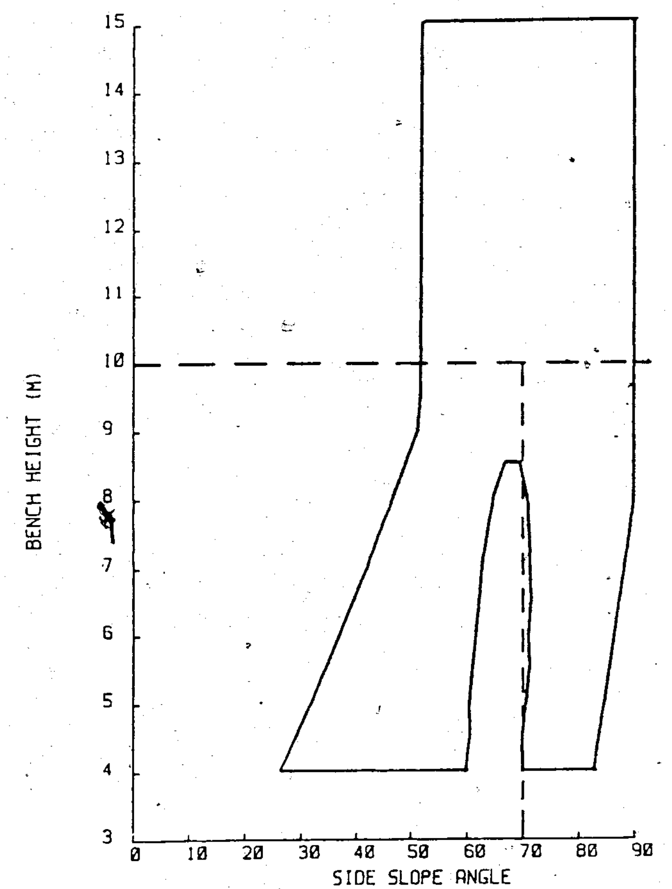
NOTE: A SIDE SLOPE ANGLE OF 90 DEGREES CAN ALWAYS BE FORMED

FIGURE 6.8

RANGE OF SIDE SLOPE ANGLES AS A FUNCTION OF HEIGHT AND FRONT SLOPE ANGLE FOR THE DROPPING CUT (MODEL A)

O&K SH 630

FRONT SLOPE ANGLE 45 MAX SLEV ANGLE SLOPE SIDE 65 VERTICAL WHEEL FREE ANGLE 59



NOTE: A SIDE SLOPE ANGLE OF 90 DEGREES CAN ALWAYS BE FORMED

FIGURE 6.9

Model D4-A

FSA	45 degrees
SSA	80 degrees
ψs	70 degrees
Advance	2.5 meters
Height	10 meters

As described in Section 4.3.3 (Model A), the range given by equation 6.1, can be changed by changing the maximum slew angle on the slope side, ψs; thereby, allowing a side slope angle which may fall within zone 2, (equation 6.2b), to be formed. This possibility must also be tested. Using figure 6.9, the slope model selected is:

Model D5-A

FSA	45 degrees
SSA	70 degrees
ψs	65 degrees
Advance	2.5 meters
Height	10 meters

Model D5-A is identical to Model D3-A, except for the maximum slew angle, ψs. A front slope angle of 45 degrees is used because at this angle the predicted side slope angle range conforms to that given by equation 6.1.

The assumption used in Model B also outputs a range of side slope angles given by equation 6.1. To test this model, one slope must be selected from each of the three zones given by equations 6.2a/b/c. Using figure 6.10, the selected slopes are:

Model D1-B

FSA	60 degrees
SSA	70 degrees
ψ_s	89 degrees
Advance	2.5 meters
Height	6 meters

Model D2-B

FSA	60 degrees
SSA	82 degrees
ψ_s	89 degrees
Advance	2.5 meters
Height	6 meters

Model D3-B

FSA	60 degrees
SSA	85 degrees
ψ_s	89 degrees
Advance	2.5 meters
Height	6 meters

With these three models, relationship Model B will either be confirmed, or rejected.

Model C outputs a range of side slope angle conforming to:

$$\alpha_{min} \leq \alpha \leq \alpha_{max} \qquad 6.3$$

where

α_{min} = Minimum side slope angle

α_{max} = Maximum side slope angle

To confirm, or reject, Model C, one slope must be selected at, or close, to the minimum side slope angle, (αmin), one between the maximum and minimum side slope angles, (αmin and αmax), and one greater than the maximum side slope angle, (αmax). The models selected, (using figure 6.11), are:

Model D1-C

FSA	60 degrees
SSA	50 degrees
ψs	70 degrees
Advance	2.5 meters
Height	10 meters

Model D2-C

FSA	75 degrees
SSA	60 degrees
ψs	70 degrees
Advance	5 meters
Height	10 meters

Model D3-C

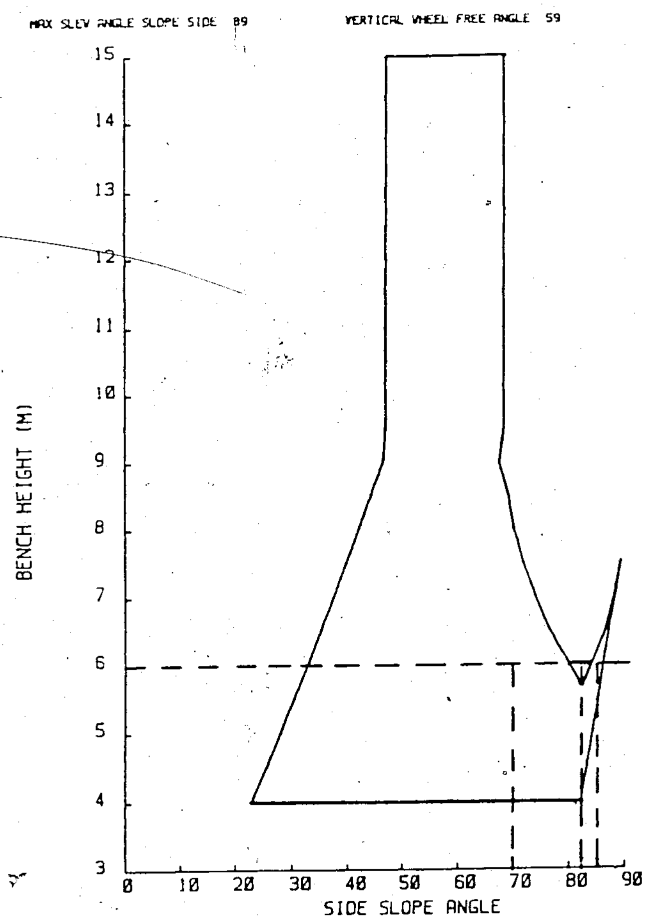
FSA	75 degrees
SSA	70 degrees
ψs	70 degrees
Advance	5 meters
Height	10 meters

In all the slopes constructed to test the side slope angle relationships, all parameters, (other than the side slope angles), are selected using the other models developed for the dropping cut.

See Appendix III for a list of the slew angles and front slope distances used to construct these models.

RANGE OF SIDE SLOPE ANGLES AS A FUNCTION OF HEIGHT FOR THE DROPPING CUT (MODEL B)

O&K SH 630

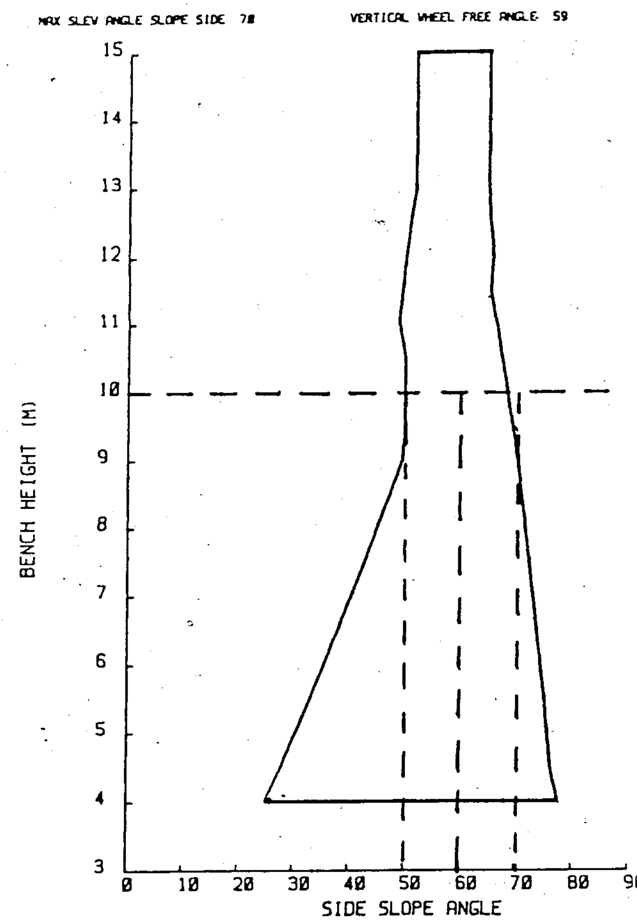


NOTE: A SIDE SLOPE ANGLE OF 90 DEGREES CAN ALWAYS BE FORMED

FIGURE 6.10

RANGE OF SIDE SLOPE ANGLES AS A FUNCTION OF HEIGHT FOR THE DROPPING CUT (MODEL C)

O&K SH 630



NOTE: A SIDE SLOPE ANGLE OF 90 DEGREES CAN ALWAYS BE FORMED

FIGURE 6.11

7.0 Results of Model Studies and Discusion

7.1 Test Results

7.1.1 *Terrace Cut*

The model was constructed with a terrace height of 4.6 meters on the top terrace, and 4.2 meters on the bottom two terraces, (see figure 7-1). This conforms to the recomended terrace heights of 0.5 to 0.7 times the digging wheel diameter given by Rasper (1975).

The objectives of Model T1 were to:

1/ Confirm the predicted maximum advance can be made

2/ Confirm the predicted front slope angle can be formed

3/ Confrim the given side slope angle can be formed

4/ Confirm the predicted cut width can be formed

The maximum advance on the top terrace is limited by the interference between the excavator crawlers and the slope toe, or by the interference between the load boom structure and the crest of the second terrace, (see Section 4.2.2). At the predicted maximum advance of 5.2 meters, the one meter safety distance between the crawlers and the slope toe has been reached, (figure 7-2). This confirms objective

FIGURE 7.1 Model T1; View showing terrace formation

FIGURE 7.2 Model T1; View showing interference between the "crawler" and the front slope toe, (line 1 is the toe line, line 2 is a safety distance, line 3 is at the start of the cut advance)

one.

Objectives two and three are confirmed by taking cross-sections through the slope at A and E, (as shown in figure 7-3). Section A is taken through the BWE centreline of advance, and confirms a front slope angle of 70 degrees is formed as predicted, (see figure 7-4). A section taken through the side slope at E, (perpendicular to the BWE centreline of advance), confirms a side slope of 60 degrees is formed, (see figure 7-5).

The confirmation of the cut width is made by measuring the distance from side slope crest to side slope crest, (as outlined in Section 4.3.4). The measurement obtained from the model is 18.8 meters; thus confirming the model predicting the cut width is correct.

7.1.2 *Dropping Cut*

The objectives of the modeling tests are:

1/ Confirm the predicted maximum advance can be made

2/ Confirm the predicted front slope angle can be formed

3/ Confirm the given side slope angle can be formed

4/ Confirm the predicted cut width can be attained

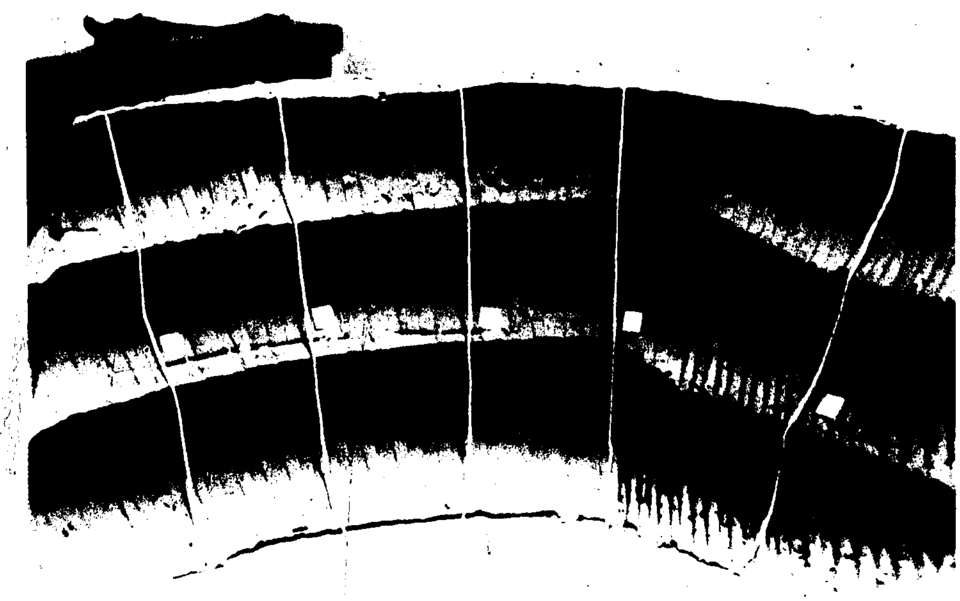


FIGURE 7.3 Model T1; View showing the location of where the cross-sections were taken.

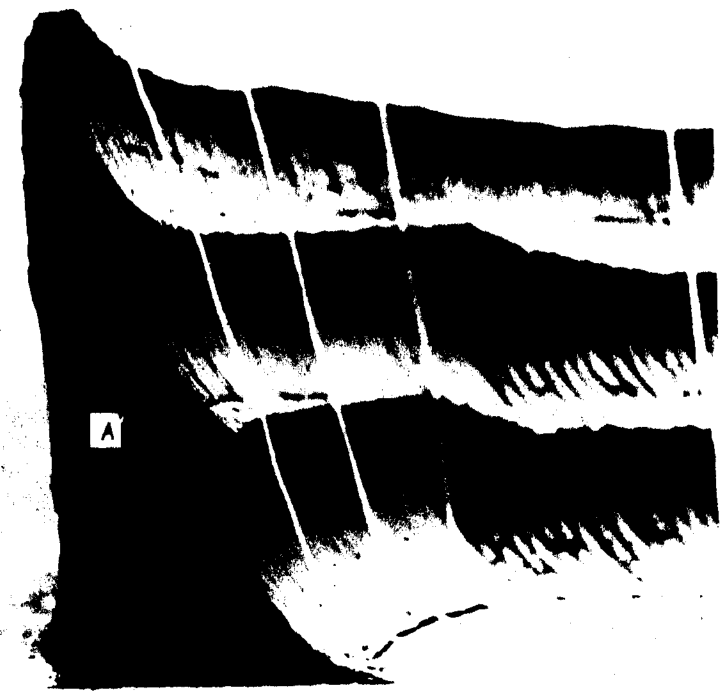


FIGURE 7.4 Model T1; Cross-section showing the front slope angle taken through the BWE centreline of advance, (slope measurement is 70 degrees)

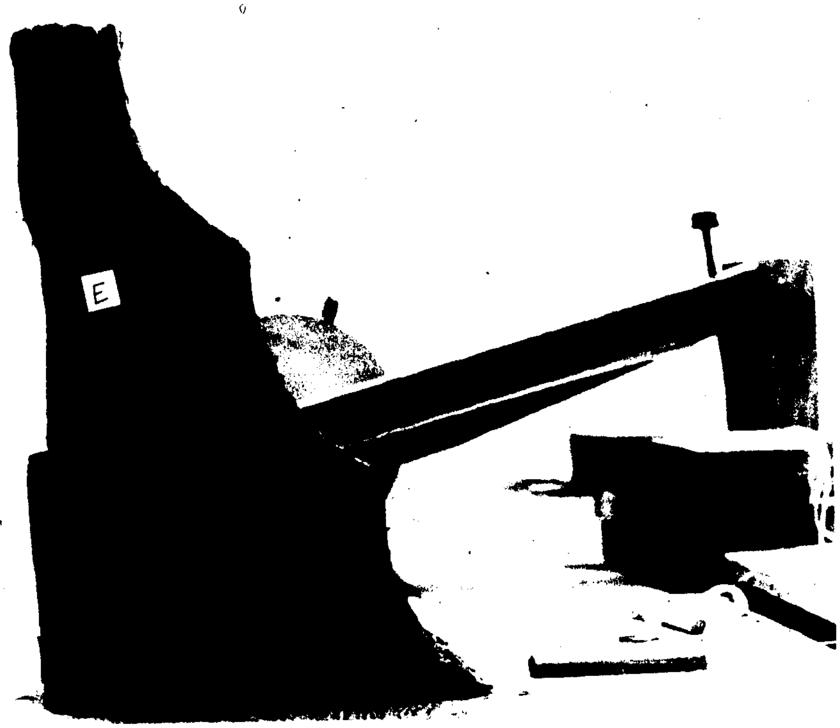


FIGURE 7.5 Model T1; Cross-section showing the side slope angle taken perpendicular to the BWE centreline of advance, (slope measurement is 60 degrees)

Objectives one, two, and four can be confirmed by using a single slope model, (Model D1). The third objective requires the construction of several slopes, because three models were developed to describe the relationship between the BWE design parameters, and the side slope angle, (see Section 4.3.3). Each of these three models was tested in order to determine how well they describe the actual side slope.

Model D1, (see Section 6.3.2), was constructed to confirm the relationships describing the minimum front slope angle, maximum advance, and the cut width. For an advance of 2.75 meters, (at the top of the slope), the distance between the crawlers and the front slope toe is one meter. This confirms that the maximum advance the excavator can make into the front face, (given a 60 degree front slope), is 2.75 meters; thus confirming objective one.

The front slope angle is confirmed by measuring the angle of the slope at the BWE centreline of advance, (Section A in figure 7.6). Cross-section A, (figure 7-7), shows a slope angle of 60 degrees, confirming objective two.

The cut width is a function of the side slope angle; therefore, it must be checked to be sure a 60 degree slope has been formed, (as required in the model slope description). The side slope angle can be checked by taking a cross-section perpendicular to the BWE centreline of advance, (Section E in figure 7-6). This cross-section is

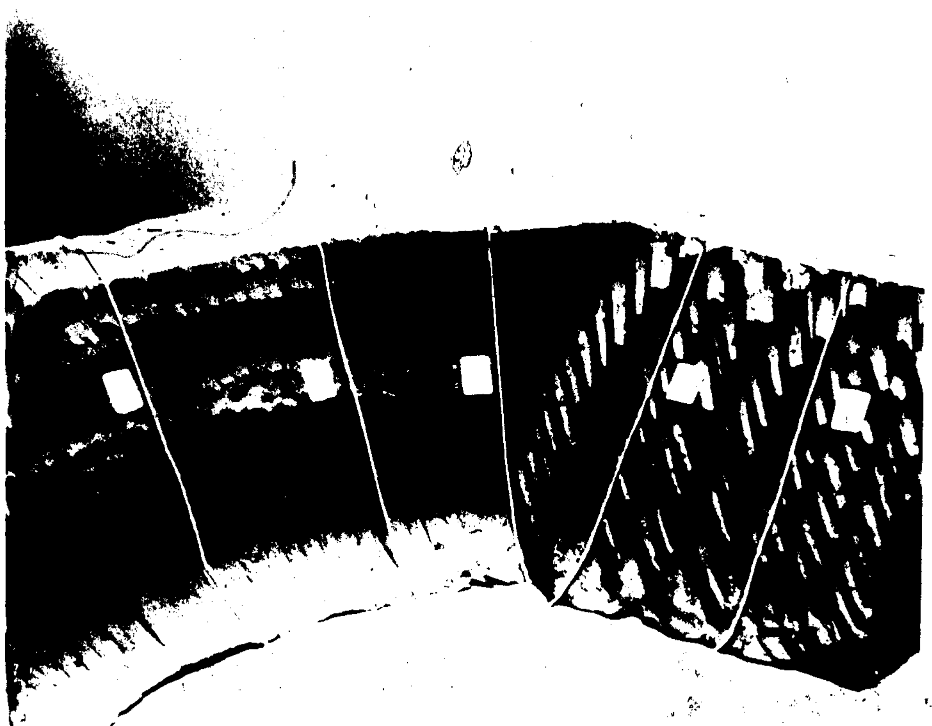


FIGURE 7.6 Model D1; View showing the location of where the cross-sections were taken

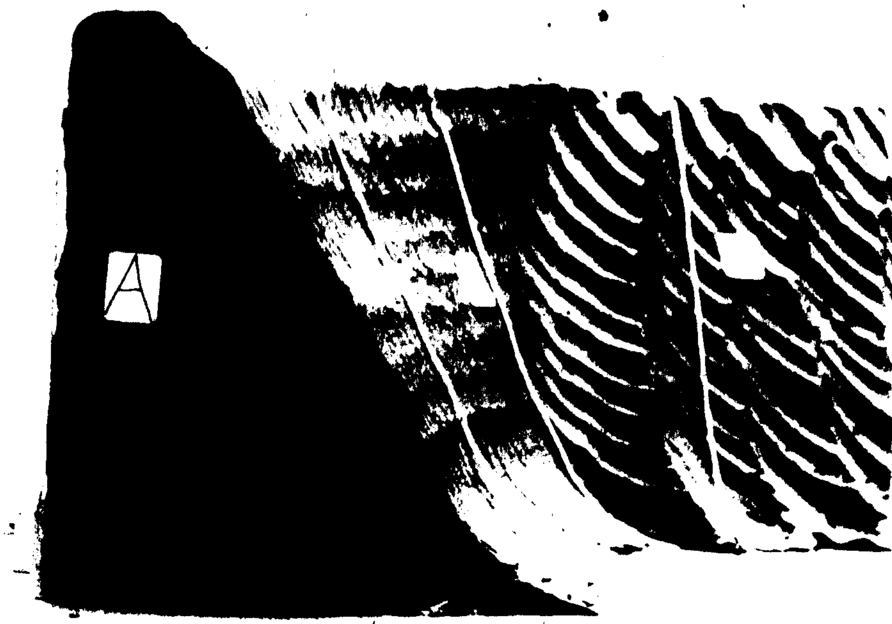


FIGURE 7.7 Model D1; Cross-section showing the front slope angle taken through the BWE centreline of advance, (slope measurement is 60 degrees)

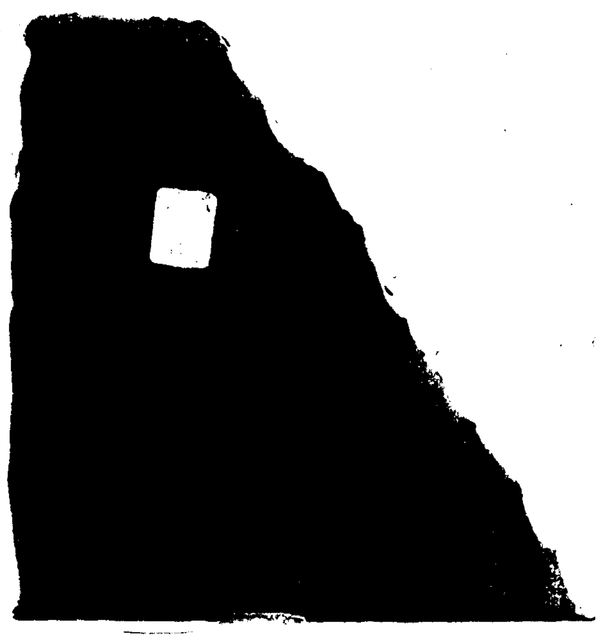


FIGURE 7.8 Model D1; Cross-section showing the side slope angle taken perpendicular to the BWE centreline of advance, (slope measurement is 60 degrees)

shown in figure 7-8, and confirms a side slope angle of 60 degrees is formed. Once the formation of the correct side slope angle has been confirmed, the cut width is measured, (taken from side slope crest to side slope crest). For the slope model, the cut width is 18 meters, and confirms objective four.

As mentioned above, several models were developed to describe the relationships between the BWE design parameters, and the side slope. Each of these models is tested separately, and either confirmed, or rejected.

The confirmation of Model A, (see Section 4.3.3: Model A), requires the construction of four slope models, (D2-A to D5-A), as given in Section 6.3.2. The determination of the side slope angle relationship for Model A, assumed the side slope to be planar; therefore, in the slope models, the side slope "sawtooth" ridges were removed, (see figure 7-6). In this way, it conforms more closely with the theory used.

The results of the slope model study for Model A are:

> <u>Model D2-A</u>; A side slope angle of 60 degrees can be formed, using a maximum slew angle of 70 degrees, (figures 7-9 and 7-10)
>
> <u>Model D3-A</u>; A side slope angle of 70 degrees can be formed using a maximum slew angle of 70 degrees, (figures 7-11 and 7-12)
>
> <u>Model D4-A</u>; A side slope angle of 80 degrees can

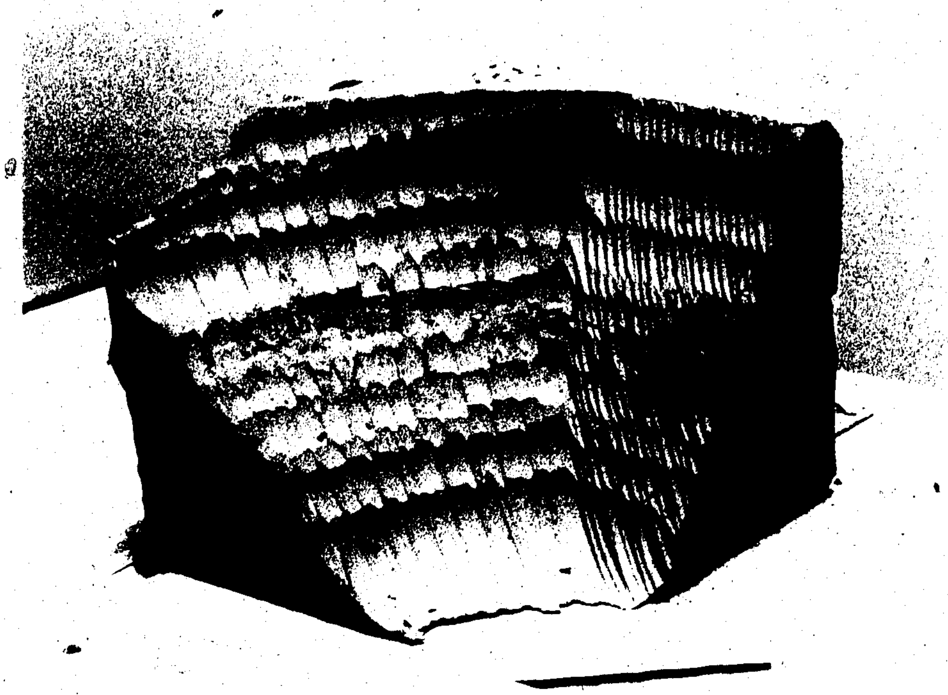


FIGURE 7.9 Model D2-A; Completed slope

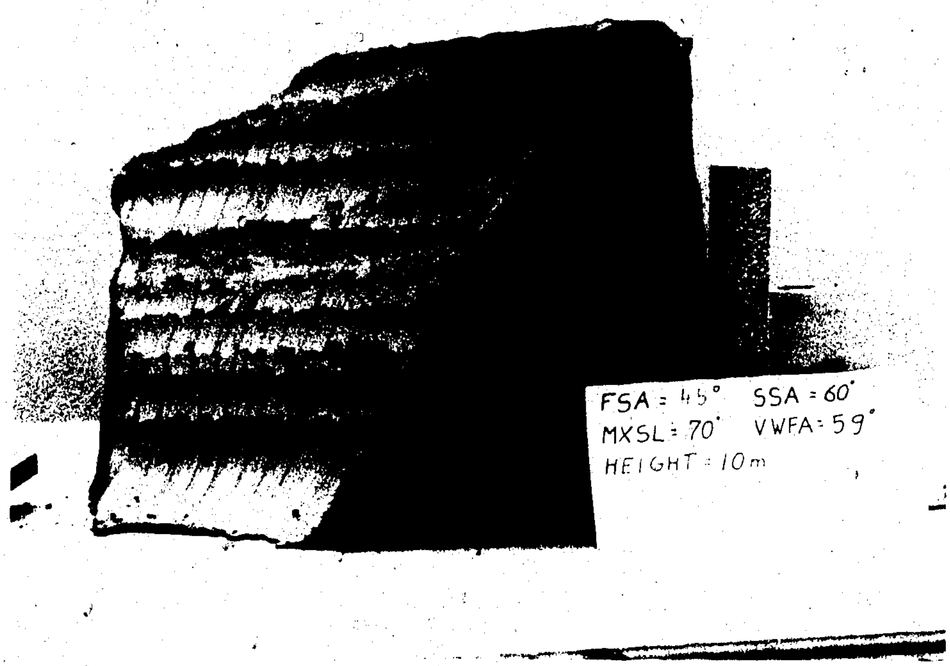


FIGURE 7.10 Model D2-A; Cross-sectional view of side slope angle, (slope measurement is 60 degrees)

FIGURE 7.11 Model D3-A; Completed slope

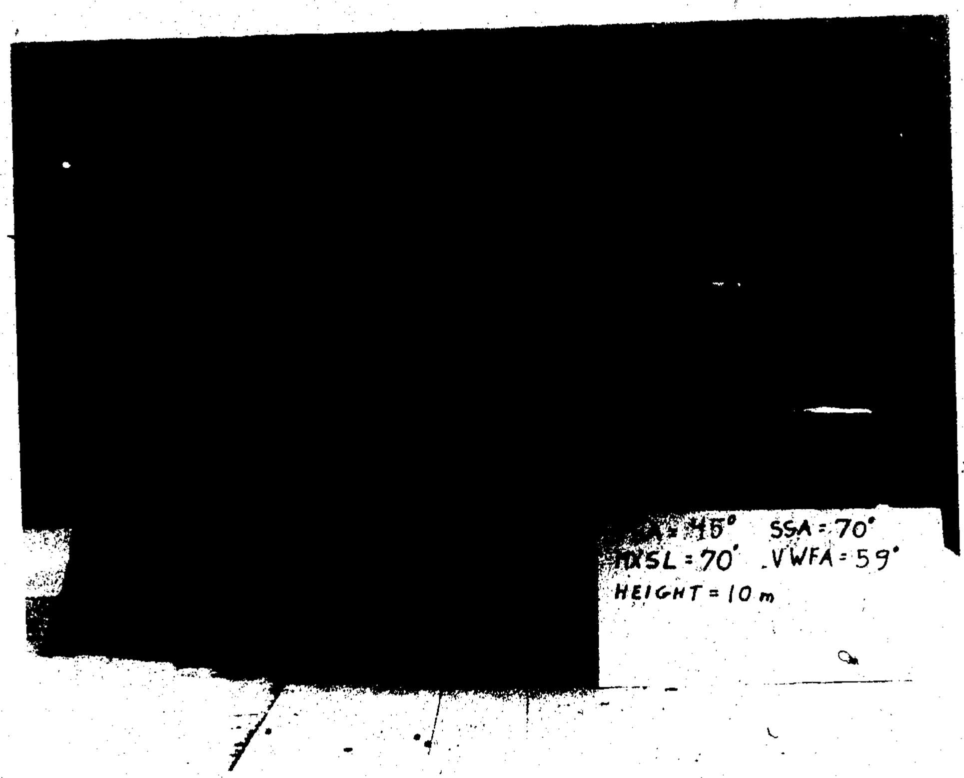


FIGURE 7.12 Model D3-A; Cross-sectional view of the side slope angle, (slope measurement is 70 degrees)

be formed, using a maximum slew angle of 70 degrees, (figures 7-13 and 7-14)

Model D5-A; A side slope angle of 70 degrees can be formed, using at a maximum slew angle of 65 degrees, (figures 7-15 and 7-16)

According to Model A, the excavator should be able to form models D2-A, D4-A and D5-A, but not model D3-A. All the model slopes can be formed at the maximum slew angles given; therefore, Model A does not describe the actual side slope well, and must be rejected.

Model B, (see Section 4.3.3: Model B), requires the formation of three slope models to be confirmed, or rejected, (Models D1-B to D3-B in Section 6.3.2). As in Model A, the relationship developed in Model B also assumes a planar side slope.

The results of the slope model study for Model B are:

Model D1-B; A side slope angle of 70 degrees can be formed, (figures 7-17 and 7-18)

Model D2-B; A side slope angle of 82 degrees can be formed, (figures 7-19 and 7-20)

Model D3-B; A side slope angle of 85 degrees can be formed, (figures 7-21 and 7-22)

To be confirmed, the excavator should be able to form models D1-B and D3-B, but not D2-B; therefore, Model B must also be

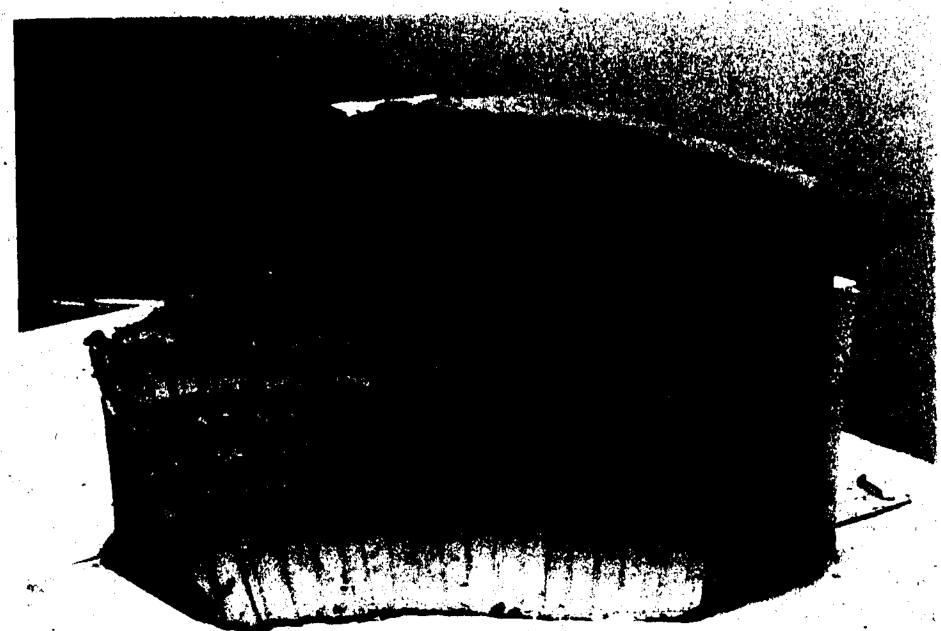


FIGURE 7.13 Model D4-A; Completed slope

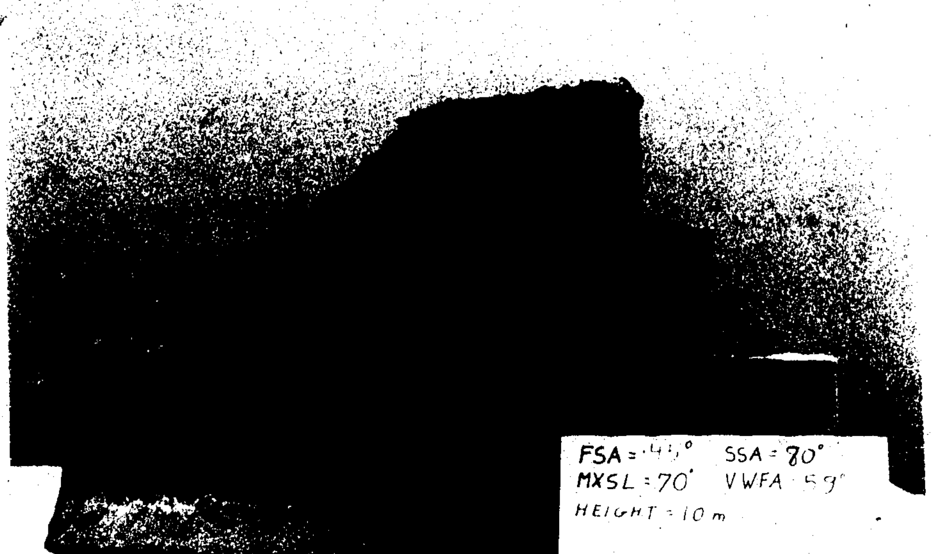


FIGURE 7.14 . Model D4-A; Cross-sectional view of side slope angle, (slope measurement is 80 degrees)

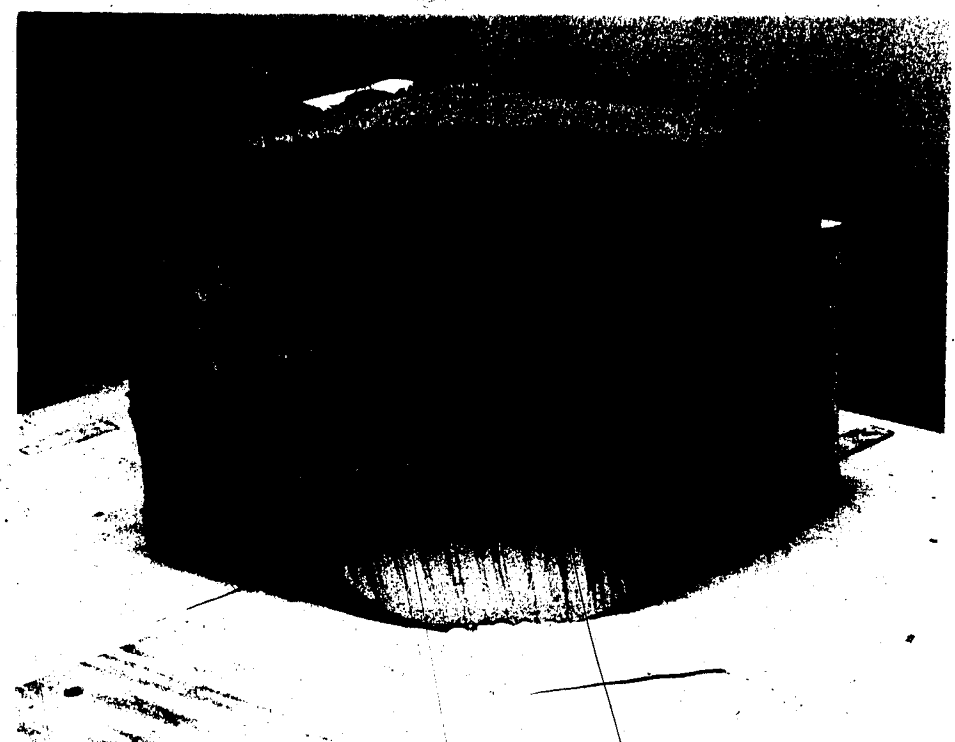


FIGURE 7.15 Model D5-A; Completed slope

FIGURE 7.16 Model D5-A; Cross-sectional view of side slope angle, (slope measurement is 70 degrees)

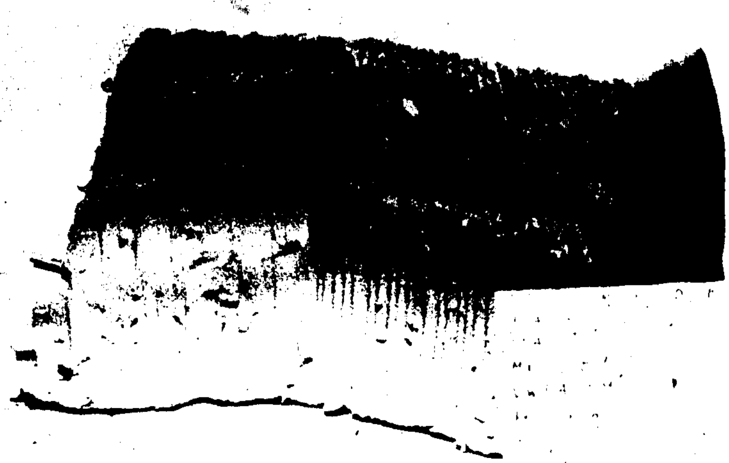


FIGURE 7.17 Model D1-B; Completed slope

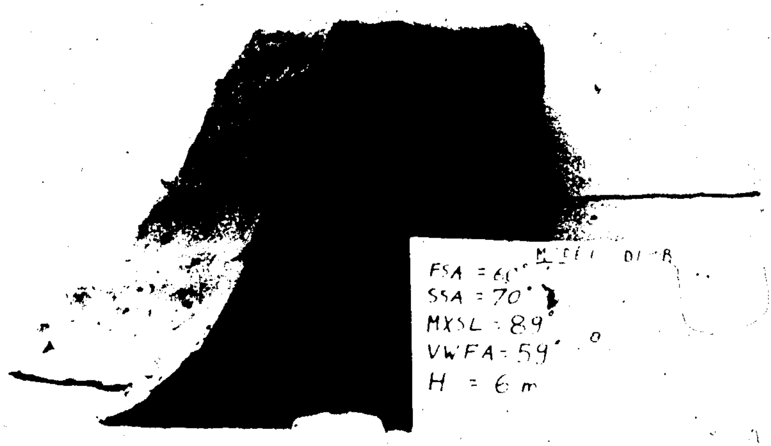


FIGURE 7.18 Model D1-B; Cross-sectional view of side slope angle, (slope measurement is 70 degrees)

FIGURE 7.19 Model D2-B; Completed slope

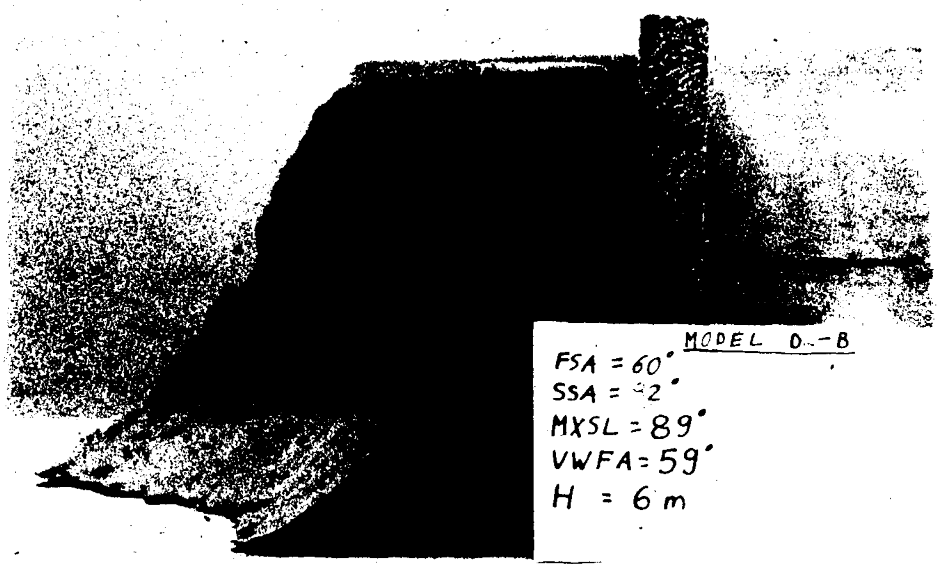


FIGURE 7.20 Model D2-B; Cross-sectional view of side slope angle, (slope measurement is 82 degrees)

FIGURE 7.21 Model D3-B; Completed slope

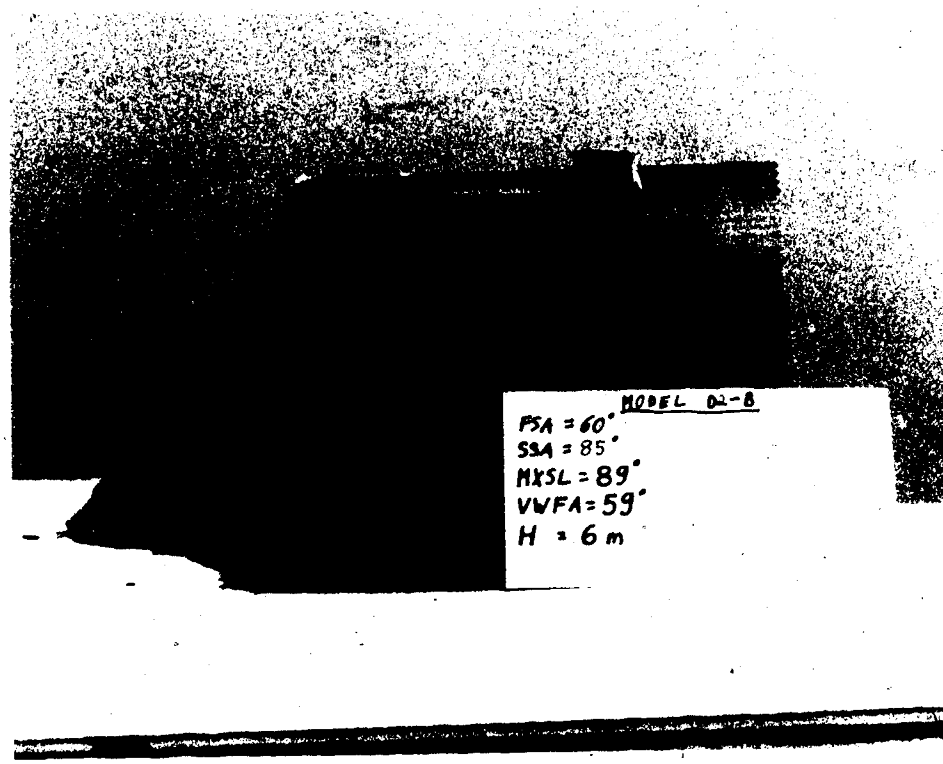


FIGURE 7.22 Model D3-B; Cross-sectional view of side slope angle, (slope measurement is 85 degrees)

rejected.

Model C uses the actual side slope to determine the side slope angle relationship. It also takes into account the "sawtooth" ridges that are formed on the side slope, (see Section 4.3.3; Model C). To confirm, or reject, this model, three slope models are selected, (Models D1-C to D3-C), as outlined in Section 6.3.2.

The results of the slope model study for Model C are:

<u>Model D1-C</u>; A side slope angle of 50 degrees can be formed, (figures 7-23 and 7-24), with no interference between the digging wheel and the side slope ridge, (figures 7-25)

<u>Model D2-C</u>; A side slope angle of 60 degrees can be formed, (figures 7-26 and 7-27), with no interference between the digging wheel and the side slope ridge, (figures 7-28 and 7-29)

<u>Model D3-C</u>; A side slope angle of 70 degrees cannot be formed, because of interference between the digging wheel and the side slope ridge, (figures 7-30 and 7-31)

To confirm Model C, the excavator should form slopes D1-C and D2-C, but not D3-C. The results of the slope model study agrees with this; therefore, Model C is accepted as the relationship which best describes the actual side slope.

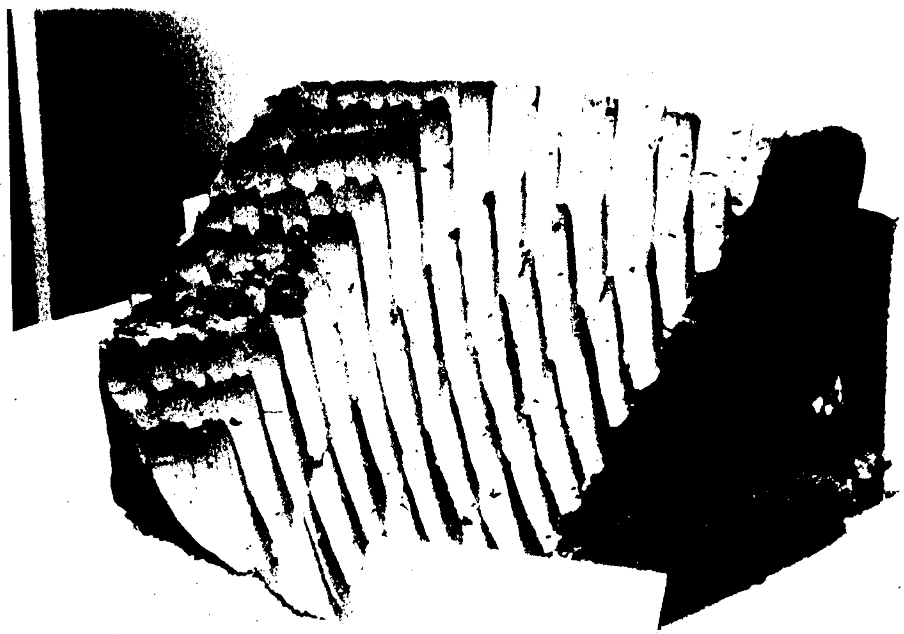


FIGURE 7.23 Model [illegible]; depleted slope

FIGURE 7.24 Model [illegible]; Cross-sectional view of side slope angle, (slope measurement is 50 degrees)

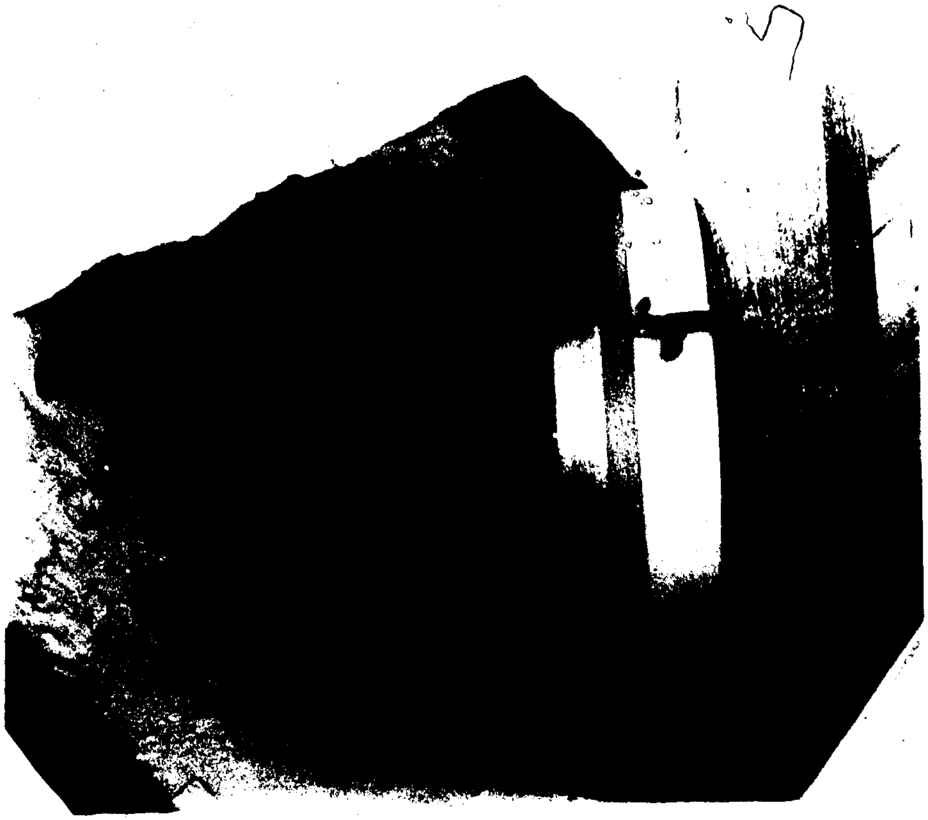


FIGURE 7.25 Model DI-C; Top view of slope showing clearance between the digging wheel and the side slope

FIGURE 7.26 Model D2-C; Completed slope

FIGURE 7.27 Model D2-C; Cross-sectional view of side slope angle, (slope measurement is 60 degrees)

FIGURE 7.28 Model D2-C; Top View of slope showing clearance between the digging wheel and the side slope

FIGURE 7.29 Model D2-C; View along the "excavator" load boom showing clearance between the digging wheel and the side slope

FIGURE 7.30 Model D3-C; Top view of slope showing the interference between the digging wheel and the side slope

FIGURE 7.31 Model D3-C; View along the "excavator" load boom showing interference between the digging wheel and the side slope

7.2 Discusion of Test Results

7.2.1 *Terrace Cut*

The objective of this investigation was to develop relationships between the BWE design parameters, and the mining face geometry. The results obtained for the terrace cut provide well-defined relations to describe this interdependence. A test conducted on these relationships, (Model T1), show them to be reliable, and thus, they can be used with confidence.

The computer models developed based on these relationships, provide output which can readily be applied to slope design. The output from these models is formatted to make them simple to understand and use, and thereby encourage their utilization.

A scale model test, (Model T1), was conducted using the output generated from these analytical models, (refer to Sections 5.2, 5.3 and 5.4). The test showed them to be very effective in describing the limits for terrace cut slopes. With minor modifications, these models can be adapted to describe the limits of any specific excavator, (see Section 7.4).

7.2.2 *Dropping Cut*

The relationships describing the minimum front slope angle and maximum advance, as well as the cut width, were confirmed by model studies, and accurately describe the results obtained through the construction of a slope model, (Model D1). Using additional slope model tests, Model C was accepted as the most representative of the actual side slope formed by an excavator. With the development of relations accurately describing the mining face, the main objective of this study has been fulfilled.

The development of the relationship describing the interdependance of the front slope angle and advance, is similar to that of the terrace cut. The results obtained from the slope model, (Model D1), confirmed the accuracy of the relationships developed. Unlike the terrace cut, their use is limited to a maximum bench height defined by Hdmax, as detailed in Section 4.3.2.

Model D1 was also used to confirm the cut width relationship which was developed in Section 4.3.4. Unlike the terrace cut, the determination of the distance between the digging wheel centre, and the actual slope, is not simply the digging wheel radius, but is dependent on the bench height, and side slope angle, (RD in Section 4.3.3). The relationships developed to describe this distance proved to be accurate, because it predicted the results obtained by the construction of the slope model D1.

The determination of a relationship between the excavator and the side slope required the development of three models, (A to C). Each of the models uses a different assumption to describe the side slope.

In Model A, the critical side slope was assumed to be on a line connecting two points: one at the crest of the slope, and the other at the toe of the slope. In this way, it was hoped a simple solution describing the side slope limitations could be developed. By using a straight line assumption, the "sawtooth" ridge that is formed on an actual slope is eliminated, (figure 7-6).

To test this model, four slopes were constructed as detailed in Section 6.3.2. For Model A to be considered an accurate representation of the side slope geometry, the "excavator", (see Section 6.2), must be able to form slopes D2-A and D4-A, but be unable to form slope D3-A because of interference between the digging wheel and the side slope. The results of the slope studies showed that all three slopes could be formed; thus Model A is not a good representation of the actual slope, and must be rejected.

With the elimination of Model A, a new assumption, (Model B), was selected, (see Section 4.3.3; Model B). In this model, the critical slope angle is also assumed to be represented by a straight line; however, the line is fixed only at the slope toe. Its direction is defined by being set perpendicular to the digging wheel centreline measured at the slope toe. As in Model A, the straight line assumption ignores the "sawtooth" ridges on the side slope.

To comfirm or reject Model B, three slope models were selected as detailed in Section 6.3.2. To be accepted, the "excavator" had to be able to form slopes D1-B and D3-B, but be unable to form slope D2-B. This is because of interference between the digging wheel the side slope. The results of the modeling study showed that all three slopes can be formed; therefore, this model must also be rejected.

Model C is similar to Model B; however, the straight line assumption is made on each slice in the cut, rather than for the entire bench height (see Section 4.3.3; Model C). In this way, the "sawtooth" ridge formed on the side slope is not ignored, because the model assumes the direction of the critical slope angle changes on each slice. This model provides only a minimum and a maximum side slope angle rather than the range of angles defined by Models A and B. The range of angles for Model C is influenced only by the maximum slew angles on the slope side of the BWE centreline of advance.

To confirm this model, three slopes are selected as detailed in Section 6.3.2. The "excavator" must be able to form slopes D1-C and D2-C, but not D3-C, for this model to be accepted. Model D3-C cannot be formed because of interference between the digging wheel and the side slope. The results of the slope model study agrees with the output obtained from this relationship; therefore, Model C accurately describes the side slope angle limitations.

With the conformation of Model C, a series of relationships has been developed which accurately describes the limits of application for a specific excavator. Using these relations, an operator can select the best machine for his operation, or have easy access to a particular excavator's operating limits to aid in the day to day planning of an operation.

As in the terrace cut, the computer models based on these relationships provide output which is formatted to make them simple to understand and use, and thereby encourage their utilization.

7.3 Example of Computer Model Output Use

To demonstrate how the analytical model output can aid in the selection of an excavator, or to design a mining face for a particular excavator, the following example is used. The examples depict a typical scenario which is worked through to the most practical solution.

7.3.1 *Terrace Cut*

Model T1 demonstrates how the analytical model output can be used. Additional design parameters are fixed in order to demonstrate the approach which can be used to develop a mining face for a hypothetical mine.

The following gives a set of mining parameters for a hypothetical operation:

1/ Front slope angle - 70 degrees

2/ Side slope angle 60 degrees

3/ Average bench height - 13 meters

4/ Cut width - minimum 20 meters

5/ Minimum advance on each cut - 4 meters

6/ Maximim slew angle on slope side - 70 to 80 degrees

7/ Excavator - O & K SH 630

The first priority is to confirm that the excavator can move in the direction of block advance. To do this, the output from the minimum front slope angle, and maximum advance model can be used, (see Table 7.1 and Table 7.2).

From the parameters given, the excavator must be able to form a front slope angle of 70 degrees, and advance at least 4 meters on each cut in the direction of block advance, at a bench height of 13 meters. Using Table 7.1, the intersection of the column representing an advance of 4 meters, (line 1), and the row at a bench height of 13 meters, (line 2), shows the minumum front slope angle which can be formed is approximately 65 degrees, (point A). This confirms that the excavator is capable of forming a front slope angle of 70 degrees, given an advance of 4 meters, and bench height of 13 meters. As a check, Table 7.2 can be used. The intersection of the column representing a front

MINIMUM OVERALL FRONT SLOPE AS A FUNCTION OF HEIGHT AND ADVANCE OF TERRACE FOR THE O&K SH 630.

'A' IS ADVANCE AND CALCULATED NUMBERS ARE FRONT SLOPE ANGLE
NOTE: FOR TERRACE CUT

				1					
HEIGHT	A=1	A=2	A=3	A=4	A=5	A=6	A=7	A=8	
4.50	2.30	2.65	3.13	3.83	4.93	6.90	11.47	32.06	
5.00	6.01	6.91	8.13	9.86	12.53	17.10	26.55	53.09	
5.50	9.58	10.97	12.84	15.45	19.34	25.68	37.34	61.56	
6.00	13.01	14.85	17.27	20.60	25.41	32.84	45.18	66.33	
6.50	16.32	18.55	21.44	25.35	30.82	38.85	51.10	69.59	
7.00	19.51	22.07	25.37	29.72	35.64	43.95	55.77	72.09	
7.50	22.58	25.44	29.07	33.76	39.98	48.34	59.60	74.16	
8.00	25.55	28.67	32.56	37.51	43.89	52.18	62.83	75.96	
8.50	28.42	31.76	35.87	41.00	47.45	55.50	65.64	77.58	
9.00	31.20	34.72	39.01	44.26	50.72	58.64	68.14	79.08	
9.50	33.90	37.58	42.00	47.32	53.74	61.42	70.40	80.50	
10.00	36.52	40.33	44.85	50.21	56.55	63.98	72.40	81.84	
10.50	39.08	42.99	47.58	52.94	59.19	66.36	74.42	83.15	
11.00	41.58	45.57	50.20	55.55	61.68	68.60	76.24	84.41	
11.50	44.02	48.08	52.[illegible]	58.04	64.04	70.71	77.98	85.66	
12.00	46.41	50.52	55.18	60.43	66.29	72.73	79.65	86.88	
12.50	48.76	52.91	57.56	62.74	68.46	74.67	81.26	88.10	
13.00	51.08	55.24	59.87	64.98 A	70.56	76.54	82.83	89.31	2
13.50	53.05	57.19	61.76	66.75	72.15	77.89	83.89	90.00	
14.00	54.48	58.54	62.99	67.82	73.01	78.49	84.20	90.00	
14.50	55.82	59.80	64.13	68.80	73.79	79.04	84.48	90.00	
15.00	57.07	60.97	65.18	69.70 B	74.50	79.53	84.74	90.00	

FOR HEIGHT LESS THAN 4.5 THERE IS NO LIMIT ON THE ADVANCE

MAXIMUM ADVANCE AS A FUNCTION OF HEIGHT AND FRONT SLOPE ANGLE FOR THE O&K SH 630

'A' IS ADVANCE @ FRONT SLOPE ANGLE
NOTE: FOR TERRACE CUT

HEIGHT	A@30	A@40	A@50	A@60	A@70 (1)	A@80	A@89
4.50	7.96	8.12	8.23	8.31	8.37	8.43	8.47
5.00	7.22	7.65	7.93	8.14	8.31	8.46	8.59
5.50	6.45	7.15	7.61	7.95	8.23	8.47	8.68
6.00	5.67	6.64	7.28	7.75	8.13	8.47	8.76
6.50	4.87	6.11	6.93	7.53	8.02	8.45	8.82
7.00	4.06	5.57	6.56	7.29	7.89	8.41	8.86
7.50	3.22	5.00	6.17	7.03	7.74	8.35	8.88
8.00	2.37	4.42	5.76	6.76	7.57	8.28	8.88
8.50	1.50	3.82	5.34	6.46	7.38	8.19	8.87
9.00	0.61	3.21	4.90	6.15	7.18	8.08	8.84
9.50	0.00	2.57	4.44	5.83	6.96	7.95	8.79
10.00	0.00	1.92	3.96	5.48	6.72	7.81	8.73
10.50	0.00	1.25	3.47	5.12	6.46	7.65	8.65
11.00	0.00	0.56	2.96	4.74	6.19	7.47	8.55
11.50	0.00	0.00	2.43	4.34	5.90	7.27	8.43
12.00	0.00	0.00	1.88	3.92	5.59	7.05	8.29
12.50	0.00	0.00	1.31	3.48	5.25	6.81	8.13
13.00	0.00	0.00	0.72	3.03	4.90 A	6.55	7.95 (2)
13.50	0.00	0.00	0.19	2.63	4.61	6.36	7.83
14.00	0.00	0.00	0.00	2.34	4.43	6.27	7.82
14.50	0.00	0.00	0.00	2.05	4.25	6.18	7.82
15.00	0.00	0.00	0.00	1.76	4.06 B	6.09	7.81

FOR HEIGHT LESS THEN 4.5 THERE IS NO LIMIT TO ADVANCE

TABLE 7.2

slope of 70 degrees, (line 1), and the row at a bench height of 13 meters, (line 2), shows a maximum advance of 4.9 meters, (point A). This is greater than the minimum advance required, and again confirms the excavator's capability of mining in the direction of block advance.

A bench height of 13 meters represents the average bench height; therefore, what is the maximum bench height the excavator can cut? Using either table 7.1 or 7.2, a maximum bench height of 15 meters can be cut, (point B).

Now that it has been confirmed the excavator can form the front slope angle, and move in the direction of block advance, the ability to form the side slope angle must be checked. To do this, Table 7.3 is used.

The maximum side slope angle permitted is 60 degrees, (detailed by given parameters). In Table 7.3, the row of interest is at a bench height representing 13 meters, (line 1). Results show that a maximum side slope angle of 60 degrees can be formed at maximum slew angles, (on the slope side), of 60, 70, 80 and 90 degrees, (points A to D). The given design parameters specify the required maximum slew angle to be between 70 and 80 degrees; thus the condition of a 60 degree side slope angle is confirmed.

As with the minimum front slope angle and maximum advance, a bench height of 13 meters is an average. The maximum bench height attainable with this excavator is 15

MINIMUM OVERALL SIDE SLOPE ANGLE AS A FUNCTION OF HEIGHT FOR THE O&K SH 630

NOTE: MINIMUM SLEW ANGLE IS 34
SL IS THE MAXIMUM SLEW ANGLE ON THE SLOPE SIDE
NOTE: FOR TERRACE CUT

HEIGHT	SL=90	SL=80	SL=70	SL=60	SL=50	SL=40
4.50	22.53	23.09	24.91	28.53	35.27	48.38
5.00	24.50	25.09	27.02	30.81	37.76	50.81
5.50	26.41	27.03	29.05	32.98	40.09	53.01
6.00	28.27	28.91	31.01	35.07	42.28	55.03
6.50	30.07	30.74	32.90	37.07	44.35	56.88
7.00	31.84	32.53	34.75	38.99	46.31	58.61
7.50	33.56	34.27	36.54	40.84	48.17	60.22
8.00	35.25	35.98	38.29	42.64	49.96	61.74
8.50	36.91	37.65	40.00	44.39	51.67	63.17
9.00	38.55	39.30	41.67	46.08	53.32	64.54
9.50	40.16	40.92	43.32	47.74	54.91	65.85
10.00	41.76	42.52	44.93	49.36	56.45	67.10
10.50	43.34	44.11	46.53	50.94	57.95	68.31
11.00	44.91	45.68	48.11	52.50	59.40	69.48
11.50	46.47	47.25	49.67	54.04	60.83	70.62
12.00	48.03	48.80	51.22	55.55	62.22	71.72
12.50	49.58	50.36	52.76	57.05	[illegible]	[illegible]
13.00	51.14 A	51.91 B	54.30 C	58.53 D	[illegible]	[illegible]
13.50	52.07	52.84	55.22	59.42	65.[illegible]	74.51
14.00	52.07	52.84	55.22	59.42	65.75	74.51
14.50	52.07	52.84	55.22	59.42	65.75	74.51
15.00	52.07	52.84 E	55.22 F	59.42	65.75	74.51

TABLE 7.3

meters; which can be obtained for both conditions of the maximum slew angle, (points E and F).

To finalize the cut design, a cut width must be defined. The maximum slew angle on the pit side of the BWE centreline of advance is limited to a maximum of 45 to 50 degrees, (Rasper, 1975). In this case, a maximum pit side slew angle of 30 degrees is selected. The output for the selected maximum slew angles is shown in Tables 7.4 and 7.5. The tables show the results obtained for a maximum pit side slew angle of 30 degrees, and a maximum slope side slew angle of 70, and 80 degrees.

Using the output provided, the intersection of the column representing a side slope angle of 60 degrees, (line 1), and the row at a bench height of 13 meters, (line 2), shows the maximum cut width under the given maximum slew angles. For a pit side slew angle of 30 degrees and slope side slew angle of 70 degrees, (Table 7.4), a cut width of 17.6 meters is obtained, (point A). For a slew angle of 80 degrees, (Table 7.5), the cut width is 18.5 meters, (point A).

As a minimum cut width of 20 meters must be maintained, these results are not acceptable. The problem may be solved by reducing the bench height, or by changing the maximum slew angles.

WIDTH OF CUT AS A FUNCTION OF HEIGHT AND SIDE SLOPE ANGLE FOR THE O&K SH 630

NOTE: MAXIMUM SLEW ANGLE FOR THE TOP TERRACE ON SIDE SLOPE SIDE IS 70
NOTE: MAXIMUM SLEW ANGLE ON THE OPEN SIDE IS 30
'W' IS THE CUT WIDTH @ THE SIDE SLOPE ANGLE FOR THE TERRACE CUT
MINIMUM SLEW ANGLE IS 34
TERRACE CUT

HEIGHT	W030	W040	W050	W060	W070	W080	W089
4.50	17.68	20.11	21.69	22.87	23.83	24.68	25.39
5.00	16.92	19.63	21.39	22.70	23.76	24.70	25.50
5.50	16.15	19.13	21.07	22.51	23.68	24.71	25.58
6.00	0.00	18.61	20.73	22.30	23.58	24.70	25.66
6.50	0.00	18.08	20.37	22.07	23.46	24.68	25.71
7.00	0.00	17.53	20.00	21.83	23.32	24.64	25.75
7.50	0.00	16.96	19.61	21.57	23.17	24.58	25.77
8.00	0.00	16.38	19.20	21.29	23.00	24.50	25.77
8.50	0.00	15.78	18.78	21.00	22.82	24.41	25.76
9.00	0.00	0.00	18.34	20.69	22.61	24.30	25.73
9.50	0.00	0.00	17.88	20.37	22.40	24.18	25.69
10.00	0.00	0.00	17.41	20.03 B	22.16	24.04	25.63
10.50	0.00	0.00	16.92	19.67	21.91	23.88	25.55
11.00	0.00	0.00	16.41	19.29	21.64	23.70	25.45
11.50	0.00	0.00	15.89	18.90	21.35	23.51	25.34
12.00	0.00	0.00	0.00	18.49	21.05	23.30	25.21
12.50	0.00	0.00	0.00	18.06	20.73	23.07	25.06
13.00	0.00	0.00	0.00	17.61 A	20.39	22.83	24.89
13.50	0.00	0.00	0.00	17.22	20.10	22.63	24.78
14.00	0.00	0.00	0.00	16.93	19.92	22.55	24.77
14.50	0.00	0.00	0.00	16.64	19.74	22.46	24.76
15.00	0.00	0.00	0.00	16.35	19.55	22.37	24.75

TABLE 7.4

WIDTH OF CUT AS A FUNCTION OF HEIGHT AND SIDE SLOPE ANGLE FOR THE O&K SH 630

NOTE: MAXIMUM SLEW ANGLE FOR THE [illegible] TERRACE ON SIDE SLOPE SIDE IS 80
NOTE: MAXIMUM SLEW ANGLE ON THE OPEN SIDE IS 30
'W' IS THE CUT WIDTH @ THE SIDE SLOPE ANGLE FOR THE TERRACE CUT
MINIMUM SLEW ANGLE IS 34

TERRACE CUT HEIGHT	W@30	W@40	W@50	1 W@60	W@70	W@80	W@89	
4.50	18.54	20.97	22.56	23.74	24.70	25.54	26.26	
5.00	17.79	20.50	22.26	23.57	24.63	25.57	26.37	
5.50	17.03	20.00	21.94	23.38	24.55	25.59	26.46	
6.00	16.25	19.49	21.61	23.18	24.46	25.58	26.54	
6.50	0.00	18.96	21.25	22.95	24.34	25.56	26.59	
7.00	0.00	18.41	20.88	22.71	24.21	25.52	26.63	
7.50	0.00	17.85	20.49	22.45	24.06	25.46	26.65	
8.00	0.00	17.26	20.09	22.18	23.89	25.39	26.66	
8.50	0.00	16.67	19.66	21.89	23.70	25.30	26.65	
9.00	0.00	16.05	19.22	21.58	23.50	25.19	26.62	
9.50	0.00	0.00	18.77	21.25	23.28	25.06	26.57	
10.00	0.00	0.00	18.29	20.91	23.04	24.92	26.51	
10.50	0.00	0.00	17.80	20.55	22.79	24.76	26.4[illegible]	
11.00	0.00	0.00	17.29	20.17 B	22.51	24.58	26.33	
11.50	0.00	0.00	16.76	19.77	22.22	24.38	26.21	
12.00	0.00	0.00	16.21	19.35	21.91	24.17	26.07	
12.50	0.00	0.00	0.00	18.92	21.58	23.93	25.92	
13.00	0.00	0.00	0.00	18.46 A	21.24	23.68	25.74	2
13.50	0.00	0.00	0.00	18.06	20.94	23.48	25.62	
14.00	0.00	0.00	0.00	17.77	20.76	23.39	25.61	
14.50	0.00	0.00	0.00	17.49	20.58	23.30	25.60	
15.00	0.00	0.00	0.00	17.20	20.40	23.21	25.60	

TABLE 7.5

If the decision is made to reduce the bench height, a maximum height of 10 meters is obtained with a maximum slew angle of 70 degrees, (Table 7.4; point B), and 11 meters with a maximum slew angle of 80 degrees, (Table 7.5; point B). Because the average bench height is 13 meters, this reduction in the bench height is unacceptable; therefore, it is necessary to look at the maximum slew angles.

Either one, or both maximum slew angles can be changed. By making several runs at different slew angles, the following combinations were found to satisfy the 20 meter cut width limitation, at a bench height of 13 meters:

Max Slew Angle Slope Side	Max Slew Angle Pit Side
70	40
80	37.5
90	35

The output used to determine these combinations is not provided because they would not add any more detail to this discussion.

From the previous discussion, the following slope designs can be defined:

	Hmax (m)	FSA (deg)	SSA (deg)	φs (deg)	φp (deg)	Cut Width (m)	Advance (m)
1	13	70	60	70	30	17.6	4
2	13	70	60	80	30	18.5	4
3	13	70	60	70	40	20.0	4
4	13	70	60	80	37.5	20.0	4
5	13	70	60	90	35	20.0	4
6	10	70	60	70	30	20.0	4
7	11	70	60	80	30	20.0	4

Of these combinations, the best design for the hypothetical mine presented would be number 4, followed by number 3.

7.3.2 *Dropping Cut*

This example is similar to Model D1, (see Section 6.3.2); however, the front slope angle has been changed to allow a more practical excavator advance. Also, several other slope design factors have been adjusted. Model C is used to predict the side slope angle because it best represents the actual slope, (see Section 7.1.2).

The following data outlines the fixed mining parameters for a hypothetical operation:

1/ Front slope angle - 70 degrees

2/ Side slope angle - 60 degrees

3/ Average bench height - 9 meters

4/ Cut width - minimum of 20 meters

5/ Minimum advance on each cut - 4 meters

6/ Maximum slew angle on slope side - 70 to 80 degrees

7/ Excavator - O&K SH 630

As with the terrace cut, the first priority is to confirm the excavator can move in the direction of block advance. To do this, the output from the minimum front slope angle and maximum advance program is used, see Tables 7.6 and 7.7.

From the known parameters, the excavator must be able to form a front slope angle of 70 degrees, and advance at least 4 meters on each cut, (in the direction of block advance), at a bench height of 9 meters. Using Table 7.6, the intersection of the column representing an advance of 4 meters, (line 1), and the row at a bench height of 9 meters, (line 2), shows that a minimum front slope angle of 65.9 degrees can be formed, (point A). This confirms the excavator can form a front slope angle of 70 degrees, and advance at least 4 meters in the direction of block advance, at a height of 9 meters. If Table 7.7 is used, the intersection of the column representing a front slope angle of 70 degrees, (line 1), and the row at a bench height of 9 meters, (line 2), shows a maximum advance of 4.75 meters,

OVERALL MINIMUM FRONT SLOPE AS A FUNCTION OF HEIGHT AND ADVANCE FOR THE O&K SH 630

'A' IS ADVANCE AND CALCULATED NUMBERS ARE FRONT SLOPE ANGLE
NOTE: FOR DROPPING CUT

HEIGHT	A=1	A=2	A=3	A=4	A=5	A=6	A=7	A=8
4.00	26.70	29.91	33.90	38.92	45.34	53.56	63.97	76.59
4.50	29.53	32.95	37.13	42.31	48.77	56.82	66.65	78.17
5.00	32.28	35.87	40.21	45.49	51.94	59.76	69.04	79.63
5.50	34.95	38.68	43.14	48.48	54.87	62.45	71.23	81.02
6.00	37.55	41.40	45.94	51.30	57.61	64.93	73.25	82.35
6.50	40.08	44.02	48.63	53.99	60.18	67.25	75.14	83.63
7.00	42.55	46.57	51.21	56.54	62.62	69.44	76.93	84.89
7.50	44.97	49.05	53.71	58.99	64.94	71.51	78.64	86.13
8.00	47.35	51.47	56.13	61.35	67.16	73.50	80.28	87.35
8.50	49.68	53.84	58.48	63.63	69.29	75.41	81.88	88.56
9.00	51.98	56.15	60.77	65.85	71.36	77.26	83.44	89.77
9.50	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
10.00	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
10.50	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
11.00	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
11.50	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
12.00	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
12.50	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
13.00	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
13.50	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
14.00	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
14.50	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
15.00	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00

TERRACE CUT ABOVE BENCH HEIGHT OF 9.100001

TABLE 7.6

ADVANCE AS A FUNCTION OF HEIGHT AND FRONT SLOPE ANGLE FOR THE O&K SH 630

'A' IS ADVANCE @ FRONT SLOPE ANGLE
NOTE: FOR DROPPING CUT

HEIGHT	A@30	A@40	A@50	A@60	A@70	A@80	A@89
4.00	2.03	4.19	5.60	6.64	7.50	8.25	8.40
4.50	1.15	3.58	5.17	6.34	7.31	8.15	8.40
5.00	0.25	2.96	4.72	6.03	7.10	8.03	8.40
5.50	0.00	2.31	4.25	5.69	6.87	7.90	8.40
6.00	0.00	1.66	3.77	5.34	6.62	7.75	8.40
6.50	0.00	0.98	3.27	4.97	6.36	7.58	8.40
7.00	0.00	0.28	2.75	4.58	6.08	7.39	8.40
7.50	0.00	0.00	2.21	4.18	5.78	7.18	8.38
8.00	0.00	0.00	1.66	3.75	5.46	6.96	8.23
8.50	0.00	0.00	1.08	3.31	5.12	6.71	8.06
9.00	0.00	0.00	0.48	2.84	4.76 A	6.45	7.88 2
9.50	0.00	0.00	0.36	2.74	4.69	6.39	7.84
10.00	0.00	0.00	0.36	2.74	4.69	6.39	7.84
10.50	0.00	0.00	0.36	2.74	4.69	6.39	7.84
11.00	0.00	0.00	0.36	2.74	4.69	6.39	7.84
11.50	0.00	0.00	0.36	2.74	4.69	6.39	7.84
12.00	0.00	0.00	0.36	2.74	4.69	6.39	7.84
12.50	0.00	0.00	0.36	2.74	4.69	6.39	7.84
13.00	0.00	0.00	0.36	2.74	4.69	6.39	7.84
13.50	0.00	0.00	0.36	2.74	4.69	6.39	7.84
14.00	0.00	0.00	0.36	2.74	4.69	6.39	7.84
14.50	0.00	0.00	0.36	2.74	4.69	6.39	7.84
15.00	0.00	0.00	0.36	2.74	4.69 B	6.39	7.84

TERRACE CUT ABOVE BENCH HEIGHT OF 9.100001

TABLE 7.7

(point A). This is greater than the minimum advance required, and again confirms that it is possible to form the required front slope angle and advance.

A bench height of 9 meters represents an average bench height. The excavator may be required to cut slopes greater than this; therefore, one should determine the maximum bench height which can be cut by the excavator.

From Tables 7.6 and 7.7, it can be noticed that the values are constant for bench heights above 9 meters. This is because a terrace cut must be used above this height. For an explanation, see Section 4.3.2. The value obtained at a bench height of 9.2 meters, can be applied to bench heights above this; therefore, the maximum bench height which can be cut is 15 meters, (Tables 7.6 and 7.7; point B).

Now that the formation of the front slope angle and excavator advance has been confirmed, the side slope must be checked. To do this, Model C is used.

The maximum side slope angle permitted is 50 degrees, and must fall within the range given by model C. The range of side slope angles depends on the maximum slew angle on the slope side of the BWE centreline of advance. From the given parameters, the output for maximum slew angles of 70 and 80 degrees must be looked at, (Tables 7.8 and 7.9). At a slope height of 9 meters, (line 1), a side slope angle of

RANGE OF SIDE SLOPE ANGLES AS A FUNCTION OF HEIGHT FOR THE O&K SH 630

NOTE: DROPPING CUT, MODEL C
MAXIMUM SLEW ANGLE IS 70
VERTICAL WHEEL FREE ANGLE IS 59

HEIGHT	MINSSA	MAXSSA
4.00	25.03	77.43
4.50	27.74	76.06
5.00	30.37	75.49
5.50	32.94	74.89
6.00	35.44	74.23
6.50	37.89	73.57
7.00	40.28	72.95
7.50	42.62	72.24
8.00	44.93	71.56
8.50	47.20	70.88
9.00	49.43	70.17 1
9.50	49.87	69.22
10.00	49.87	68.21
10.50	49.87	67.17
11.00	48.62	66.11
11.50	49.12	65.06
12.00	49.80 A	65.59
12.50	50.62	65.02
13.00	51.55	64.70
13.50	51.55	64.70
14.00	51.55	64.70
14.50	51.55	64.70
15.00	51.55	64.70

TABLE 7.8

TERRACE CUT IS USED ABOVE A BENCH HEIGHT OF 9.100001

RANGE OF SIDE SLOPE ANGLES AS A FUNCTION OF HEIGHT FOR THE O&K SH 630

NOTE: DROPPING CUT, MODEL C
MAXIMUM SLEW ANGLE IS 80
VERTICAL WHEEL FREE ANGLE IS 59

HEIGHT	MINSSA	MAXSSA
4.00	23.35	85.02
4.50	25.93	84.75
5.00	28.45	83.42
5.50	30.92	82.03
6.00	33.34	80.57
6.50	35.72	77.99
7.00	38.05	77.02
7.50	40.36	76.01
8.00	42.63	75.03
8.50	44.88	74.05
9.00	47.11	73.00 1
9.50	47.55	72.28
10.00	47.55	71.63
10.50	45.92	70.87
11.00	46.20	70.07
11.50	46.74	69.26
12.00	47.44	69.67
12.50	48.28	69.07
13.00	49.22	68.77
13.50	49.22	68.77
14.00	49.22	68.77
14.50	49.22	68.77
15.00	49.22 A	68.77

TABLE 7.9

TERRACE CUT IS USED ABOVE A BENCH HEIGHT OF 9.100001

50 degrees falls within the predicted range for both cases of the maximum slew angle. This confirms the excavator can form the side slope angle at the given parameters.

Above a bench height of 9.2 meters, the output for Model C is not constant as it is for the minimum front slope angle and maximum advance program. This is because of the influence the terrace cut has on the side slope above a a bench height of 9.2 meters. As mentioned above, the side slope angle range depends on the maximum slew angle. At a maximum side slope angle of 50 degrees and a maximum slew angle of 70 degrees, the maximum bench height which can be formed is 12 meters, (Table 7.8; point A); while for a maximum slew angle of 80 degrees, the maximum bench height is 15 meters, (Table 7.9; point A).

In this example, an initial pit side slew angle of 30 degrees is selected. The output obtained for the selected maximum slew angles on the slope side is provided in Tables 7.10 and 7.11. Using the tables provided, the intersection of the column representing a side slope of 50 degrees, (line 1), and the row at a height of 9 meters, (line 2), gives the maximum cut width for the given maximum slew angles. For a pit side slew angle of 30 degrees, and a slope side slew angle of 70 degrees, a cut width of 16 meters is obtained, (Table 7.10; point A). For a slope side slew angle of 80 degrees, the cut width is 16.75 meters, (Table 7.11; point A). Depending on the operation, these may of may not be

MAXIMUM WIDTH OF CUT AS A FUNCTION OF HEIGHT AND SIDE SLOPE ANGLE FOR THE O&K SH 630

NOTE: MAXIMUM SLEW ANGLE ON SIDE SLOPE SIDE IS 70

NOTE: MAXIMUM SLEW ANGLE ON PIT SIDE IS 30

NOTE: FOR DROPPING CUT

NOTE: 'W' IS THE CUT WIDTH @ THE SIDE SLOPE ANGLE

HEIGHT	W@30	W@40	W@50 1	W@60	W@70	W@80	W@89
4.00	17.32	19.48	21.04	22.34	23.53	24.70	25.79
4.50	0.00	18.87	20.61	22.04	23.34	24.60	25.77
5.00	0.00	18.25	20.17 B	21.73	23.13	24.48	25.73
5.50	0.00	17.61	19.70	21.40	22.91	24.35	25.68
6.00	0.00	16.95	19.22	21.05	22.66	24.21	25.61
6.50	0.00	0.00	18.73	20.68	22.41	24.04	25.53
7.00	0.00	0.00	18.22	20.30	22.13	23.86	25.43
7.50	0.00	0.00	17.69	19.90	21.84	23.66	25.31
8.00	0.00	0.00	17.14	19.48	21.53	23.44	25.17
8.50	0.00	0.00	16.57	19.05	21.20	23.21	25.01
9.00	0.00	0.00	15.98 A	18.59	20.85	22.95	24.84 2
9.50	0.00	0.00	0.00	18.27	20.63	22.83	24.79
10.00	0.00	0.00	0.00	18.06	20.50	22.77	24.79
10.50	0.00	0.00	0.00	18.04	20.49	22.76	24.79
11.00	0.00	0.00	0.00	18.03	20.48	22.75	24.79
11.50	0.00	0.00	0.00	17.99	20.47	22.75	24.78
12.00	0.00	0.00	0.00	17.89	20.45	22.74	24.78
12.50	0.00	0.00	0.00	17.73	20.39	22.74	24.78
13.00	0.00	0.00	0.00	17.50	20.27	22.71	24.78
13.50	0.00	0.00	0.00	17.50	20.27	22.71	24.78
14.00	0.00	0.00	0.00	17.50	20.27	22.71	24.78
14.50	0.00	0.00	0.00	17.50	20.27	22.71	24.78
15.00	0.00	0.00	0.00	17.50	20.27	22.71	24.78

TERRACE CUT IS USED ABOVE BENCH HEIGHT OF 9.100001

TABLE 7.10

MAXIMUM WIDTH OF CUT AS A FUNCTION OF HEIGHT AND SIDE SLOPE ANGLE FOR THE O&K SH 630

NOTE: MAXIMUM SLEW ANGLE ON SIDE SLOPE SIDE IS 80
NOTE: MAXIMUM SLEW ANGLE ON PIT SIDE IS 30
NOTE: FOR DROPPING CUT
NOTE: 'W' IS THE CUT WIDTH @ THE SIDE SLOPE ANGLE

HEIGHT	W@30	W@40	W@50 1	W@60	W@70	W@80	W@89
4.00	18.12	20.28	21.86	23.17	24.37	25.56	26.67
4.50	17.25	19.68	21.43	22.87	24.18	25.46	26.65
5.00	0.00	19.05	20.98	22.55	23.97	25.34	26.62
5.50	0.00	18.41	20.51	22.22	23.74	25.21	26.56
6.00	0.00	17.75	20.03 B	21.87	23.50	25.06	26.49
6.50	0.00	17.08	19.53	21.50	23.24	24.89	26.40
7.00	0.00	0.00	19.02	21.11	22.96	24.71	26.30
7.50	0.00	0.00	18.48	20.71	22.66	24.50	26.17
8.00	0.00	0.00	17.92	20.28	22.34	24.28	26.03
8.50	0.00	0.00	17.35	19.84	22.01	24.04	25.86
9.00	0.00	0.00	16.76 A	19.38	21.65	23.77	25.68 2
9.50	0.00	0.00	16.30	19.05	21.43	23.65	25.63
10.00	0.00	0.00	0.00	18.85	21.30	23.59	25.63
10.50	0.00	0.00	0.00	18.84	21.30	23.58	25.63
11.00	0.00	0.00	0.00	18.84	21.30	23.58	25.63
11.50	0.00	0.00	0.00	18.82	21.29	23.58	25.63
12.00	0.00	0.00	0.00	18.73	21.29	23.58	25.63
12.50	0.00	0.00	0.00	18.57	21.23	23.58	25.63
13.00	0.00	0.00	0.00	18.34	21.12	23.56	25.63
13.50	0.00	0.00	0.00	18.34	21.12	23.56	25.63
14.00	0.00	0.00	0.00	18.34	21.12	23.56	25.63
14.50	0.00	0.00	0.00	18.34	21.12	23.56	25.63
15.00	0.00	0.00	0.00	18.34	21.12	23.56	25.63

TERRACE CUT IS USED ABOVE BENCH HEIGHT OF 9.100001

TABLE 7.11

acceptable.

In the parameters fixed at the start of this section, a minimum cut width of 20 meters is required; thus these results are unacceptable. To form the cut width required, one can reduce the bench height, or change the maximum slew angles.

If the bench height is reduced, a height of approximately 5 meters is obtained at a maximum slope side slew angle of 70 degrees, (Table 7.10; point B), and a height of approximately 6 meters for an angle of 80 degrees, (Table 7.11; point B). The average slope height is 9 meters, and this much reduction in bench height is an unacceptable solution.

By changing the maximum slew angles, (either one or both), a cut width of 20 meters can be obtained. By making several runs at different combinations of the maximum slew angles, the following combinations were found to satisfy the 20 meter cut width limitation, at a bench height of 9 meters:

Max Slew angle Slope Side	Max Slew angle Pit Side
70	52.5
80	47.5
90	47.5

The output used to determine these combinations is not provided because it would not add any detail to this discussion.

From the previous discussion, the following slope designs can be defined:

	Hmax (m)	FSA (deg)	SSA (deg)	Ψ_s (deg)	Ψ_p (deg)	Cut Width (m)	Advance (m)
1	9	70	50	70	30	16.0	4
2	9	70	50	80	30	16.8	4
3	5	70	50	70	30	20.0	4
4	6	70	50	80	30	20.0	4
5	9	70	50	70	52.5	20.0	4
6	9	70	50	80	47.5	20.0	4
7	9	70	50	90	47.5	20.0	4

Of these combinations, the best design for the hypothetical operation is row 6, followed by row 5.

7.4 Future Work

The computer models in this study, have been developed for use with compact (standard) BWEs; however, they can be modified to describe the limits for any size BWE. To do this, the following modifications must be done;

1/ The bench height interval at which the values are calculated, should be input by user; (at present, the interval is set internally to 0.5 meters)

2/ The advances used to calculate the minimum front angles, should be input by user: [up to the maximum of 8]; (At present the advance is set from 1 to 8 meters, in 1 meter intervals)

3/ The size of the the storage variable must be increased to accomodate all the output generated

They are limited however, to benches formed above crawler level. Because of this, they cannot be used for deep cutting BWEs.

To develop relationships which can be used to describe the limits for a bench below the crawler level, the following BWE design parameters, (as outlined in Section 4.1.1), must be incorporated into relationships:

1/ Maximum depth the excavator can cut below the crawler level (HD)

2/ Maximum elevation of the discharge boom (DM)

3/ Minimum elevation of the discharge boom (DD)

4/ Length of discharge boom (DB)

5/ Minimum angle permitted between the load boom and discharge boom (χ)

In addition to these parameters, a safety distance must be established between the leading edge of the excavator crawler, and the slope crest.

For this series of models to be complete, the addition of a productivity model is necessary. Many good models have already been developed to do this (Venkataramani, 1970), and relationships describing either single excavator productivity, or system productivity, have already been developed, (Hoffmann, 1982 (1&2)).

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APPENDIX I

APPENDIX I-1

```
LOAD"B:TRFSA1.BAS
Ok
RUN
NAME OF BWE? O&K SH 630
DIGGING WHEEL DIAMETER? 8.4
LENGTH OF BWE LOAD BOOM? 14.35
MAXIMUM LIFT OF DIGGING WHEEL CENTRE? 13.3
THE DISTANCE 'E'? -1.1
ELEVATION OF LOAD BOOM PIVOT POINT? 8.15
DISTANCE BETWEEN LATERAL CENTER LINE AND FRONT EDGE OF CRAWLER, IE. CL? 4.65
DISTANCE BETWEEN CENTRE LINE OF ADVANCE AND OUTSIDE EDGE OF CRAWLER, IE. CW? 4.9
5
DO YOU WANT TO PLOT THE DATA, (Y/N)? N
DO YOU WANT CALCULATIONS FOR ADVANCE AS A FUNCTION OF HEIGHT AND SLOPE ANGLE, (Y
/N)? Y
DO YOU WANT TO PLOT THE DATA, (Y/N)? N
Ok




1LIST  2RUN  3LOAD"  4SAVE"  5CONT 6,"LPT1 7TRON 8TROFF9KEY   0SCREEN
```

```
10 DIM TAH(9,40)
20 PI=3.141593
30 INPUT "NAME OF BWE";NAME1$
40 INPUT "DIGGING WHEEL DIAMETER";D
50 INPUT "LENGTH OF BWE LOAD BOOM";LB
60 INPUT "MAXIMUM LIFT OF DIGGING WHEEL CENTRE";HM
70 INPUT "THE DISTANCE 'E'";E
80 INPUT "ELEVATION OF LOAD BOOM PIVOT POINT";Y
90 INPUT "DISTANCE BETWEEN LATERAL CENTER LINE AND FRONT EDGE OF CRAWLER, IE. CL";CL
100 INPUT "DISTANCE BETWEEN CENTRE LINE OF ADVANCE AND OUTSIDE EDGE OF CRAWLER, IE. CW";CW
110 LPRINT "MINIMUM OVERALL FRONT SLOPE AS A FUNCTION OF HEIGHT AND ADVANCE OF TERRACE FOR"
115 LPRINT "THE ";NAME1$
120 LPRINT " "
130 LPRINT "'A' IS ADVANCE AND CALCULATED NUMBERS ARE FRONT SLOPE ANGLE"
140 LPRINT "NOTE: FOR TERRACE CUT"
145 LPRINT " "
150 LPRINT "HEIGHT    A=1     A=2     A=3     A=4     A=5     A=6     A=7     A=8"
160 BTAD=(Y-(.5*D))/LB
170 BTDR=ATN(BTAD/SQR(1-BTAD*BTAD))
180 F1=(LB-E)*COS(BTDR)
190 F2=((F1^2)-(CW^2))^.5
200 F=1+(F1-F2)
210 HHMIN%=(D/2)/.5
215 HMIN=HHMIN%*.5
216 HMIN2=HMIN
217 IF HMIN<(D/2) GOTO 218 ELSE GOTO 220
218 HMIN=HMIN+.5
219 GOTO 217
220 H=HMIN
230 HHMAX%=(HM+(.2*D))/.5
235 HMAX=HHMAX%*.5
236 ICOUNT=(HMAX-HMIN)*2+1
240 I%=1
244 J%=1
246 J=1
250 IF H>HMAX GOTO 420
260 A=1
270 I=2
280 IF H>HM THEN BTAH=(HM-Y)/LB
290 IF (H<=HM) AND (H>Y) THEN BTAH=(H-Y)/LB
300 IF (H<=Y) AND (H>=HMIN) THEN BTAH=(Y-H)/LB
310 BTHR=ATN(BTAH/SQR(1-BTAH*BTAH))
320 AA=(LB*COS(BTHR)-E)-(A+F+CL)
324 IF AA<=0! THEN TAH(I,J)=90!
326 IF AA<=0! GOTO 360
327 IF (H-(D/2))<0 THEN TAH(I,J)=0
328 IF (H-(D/2))<0 GOTO 360
330 BB=(H-(.5*D))/AA
340 TAH(I,J)=ATN(BB)
350 TAH(I,J)=TAH(I,J)*180/PI
360 I=I+1
370 A=A+1
380 IF A<9 GOTO 320
385 TAH(1,J)=H
```

```
5010 HMAX1=INT(HMAX+.5):HMIN1=INT(HMIN2-.5)
5020 YFACT=(1300/(HMAX1-HMIN1)):XFACT=80/9

5030 PRINT #1,";: A H " 'INITIALIZE PLOTTER
5040 PRINT #1,"U 0,0 D 0,0 0,2200 1700,2200 1700,0 0,0 "
5050 PRINT #1,"U 300,200 D 300,200 300,2000 1500,2000 1500,200 300,200 "
5060 PRINT #1, "U 400,1940 S11+ MINIMUM OVERALL FRONT SLOPE ANGLE AS A FUNCTION OF HEIGHT _ "
5065 PRINT #1, "U 730,1905 S11+ FOR THE TERRACE CUT _ "
5070 PRINT #1, "U 750,1845 S12 " NAME1$ " _ "
5080 FOR K=0 TO 90 STEP 10
5090 X$=STR$(INT(K*XFACT+500.5)):YY$="460":HMIN$="450"
5100 IF K=0 THEN PRINT #1," U "X$","HMIN$
5110 PRINT #1, " D "X$","HMIN$
5120 PRINT #1, " D "X$","YY$
5130 PRINT #1, " D "X$","HMIN$
5140 NEXT K
5150 FOR K=0 TO 90 STEP 10
5160 X$=STR$(INT(K*XFACT+460.5)):XX$=STR$(K):Y$="420.5"
5170 PRINT #1," U "X$","Y$" S11+ "XX$" _ "
5180 NEXT K
5190 PRINT #1, " U 500,450 "
5200 FOR K=HMIN1 TO HMAX1 STEP 1
5210 X$="500":X1$="510":Y$=STR$(INT((K-HMIN1)*YFACT+450.5))
5220 PRINT #1, " D "X$","Y$
5230 PRINT #1, " D "X1$","Y$
5240 PRINT #1, " D "X$","Y$
5250 NEXT K
5260 FOR K=HMIN1 TO HMAX1 STEP 1
5270 X$="415":Y$=STR$(INT((K-HMIN1)*YFACT+450.5)):YY$=STR$(K)
5280 PRINT #1,"U "X$","Y$
5290 PRINT #1," S11+ "YY$" _"
5300 NEXT K
5310 PRINT #1,"U 800,380":PRINT #1," S11+ FRONT SLOPE ANGLE  _ "
5320 PRINT #1,"U 350,900":PRINT #1," S41+ BENCH HEIGHT (M) _ "
5330 PRINT #1," EL "
5340 FOR I=2 TO 9
5350 IF I=2 THEN PRINT #1,"L0 "
5360 IF I=3 THEN PRINT #1,"L1 "
5370 IF I=4 THEN PRINT #1,"L3 "
5380 IF I=5 THEN PRINT #1,"L5 "
5390 IF I=6 THEN PRINT #1,"L7 "
5400 IF I=7 THEN PRINT #1,"L8 "
5402 IF I=8 THEN PRINT #1,"L9 "
5404 IF I=9 THEN PRINT #1,"L: "
5410 FOR J=1 TO ICOUNT
5420 X$=STR$(INT(TAH(I,J)*XFACT+500.5)):Y$=STR$(INT((TAH(1,J)-HMIN1)*YFACT+450.5))
5430 IF J=1 THEN PRINT #1,"U "X$,Y$" "
5440 PRINT #1,"D " X$","Y$" "
5450 NEXT J:NEXT I
5460 PRINT #1,"L0 U 550,320 D 650,320 "
5461 PRINT #1,"L1 U 800,320 D 900,320 "
5462 PRINT #1,"L3 U 1050,320 D 1150,320 "
5463 PRINT #1,"L5 U 550,290 D 650,290 "
5464 PRINT #1,"L7 U 800,290 D 900,290 "
5465 PRINT #1,"L8 U 1050,290 D 1150,290 "
```

```
390 LPRINT USING "###.##  ";TAH(1,J),TAH(2,J),TAH(3,J),TAH(4,J),TAH(5,J),TAH(6,J),TAH(7,J),TAH(8,J),
    TAH(9,J)
400 H=H+.5
405 J=J+1
410 GOTO 250
420 LPRINT " "
430 LPRINT "FOR HEIGHT LESS THAN ";HMIN;" THERE IS NO LIMIT ON THE ADVANCE"
432 INPUT "DO YOU WANT TO PLOT THE DATA, (Y/N)";ZZ$
435 IF ZZ$="Y" THEN GOSUB 5000
440 INPUT "DO YOU WANT CALCULATIONS FOR ADVANCE AS A FUNCTION OF HEIGHT AND SLOPE ANGLE, (Y/N)";Z$
450 IF Z$="N" GOTO 780
460 LPRINT " "
470 LPRINT "MAXIMUM ADVANCE AS A FUNCTION OF HEIGHT AND FRONT SLOPE ANGLE FOR THE "
475 LPRINT NAME1$
480 LPRINT " "
490 LPRINT "'A' IS ADVANCE @ FRONT SLOPE ANGLE"
500 LPRINT "NOTE: FOR TERRACE CUT"
505 LPRINT " "
510 LPRINT "HEIGHT    A@30    A@40    A@50    A@60    A@70    A@80    A@89"
520 H=HMIN
525 J=1
530 I=2
540 TAH(I,J)=99!
550 I=I+1
560 IF I<9 GOTO 540
570 IF H>HMAX GOTO 760
580 FSA=30
590 I=2
600 FSAR=FSA*PI/180
610 IF H>HM THEN BTAH=(HM-Y)/LB
620 IF (H<=HM) AND (H>Y) THEN BTAH=(H-Y)/LB
630 IF (H<=Y) AND (H>=HMIN) THEN BTAH=(Y-H)/LB
640 BTHR=ATN(BTAH/SQR(1-BTAH*BTAH))
650 AA=((D*.5)-H)/TAN(FSAR)
660 BB=LB*COS(BTHR)-E
670 TAHI=AA+BB-CL-F
675 IF TAHI<0! THEN TAHI=0!
680 TAH(I,J)=TAHI
690 I=I+1
700 FSA=FSA+10
710 IF FSA=90 THEN FSA=89
720 IF FSA<90 GOTO 600
725 TAH(1,J)=H
730 LPRINT USING "###.##  ";TAH(1,J),TAH(2,J),TAH(3,J),TAH(4,J),TAH(5,J),TAH(6,J),TAH(7,J),TAH(8,J)
735 J=J+1
740 H=H+.5
750 GOTO 570
755 YMAX=TAH(8,1)
760 LPRINT " "
770 LPRINT "FOR HEIGHT LESS THEN ";HMIN;" THERE IS NO LIMIT TO ADVANCE"
774 INPUT "DO YOU WANT TO PLOT THE DATA, (Y/N)";ZZZ$
776 IF ZZZ$="Y" THEN GOSUB 6000
780 END
5000 OPEN "COM2:2400,E,7,2,CS60000,DS60000" AS #1
5005 ON ERROR GOTO 5900
```

```
5466 PRINT #1,"L9 U 550,260 D 650,260 "
5467 PRINT #1,"L: U 800,260 D 900,260 "
5475 PRINT #1,"EL "

5476 PRINT #1,"LO "
5480 PRINT #1," U 400,290 S11+ LEGEND _"
5490 PRINT #1," U 670,320 S11 A=1 _ "
5500 PRINT #1," U 920,320 S11 A=2 _ "
5510 PRINT #1," U 1170,320 S11 A=3 _ "
5520 PRINT #1," U 670,290 S11 A=4 _ "
5530 PRINT #1," U 920,290 S11 A=5 _ "
5540 PRINT #1," U 1170,290 S11 A=6 _ "
5542 PRINT #1," U 670,260 S11 A=7 _ "
5544 PRINT #1," U 920,260 S11 A=8 _ "
5552 PRINT #1,"U 550,230 S11 A=ADVANCE _ "
5560 PRINT #1," H ":CLOSE
5570 RETURN
5900 FOR IJKL=0 TO 1000:NEXT IJKL:RESUME
6000 OPEN "COM2:2400,E,7,2,CS60000,DS60000" AS #1
6010 ON ERROR GOTO 7000
6020 HMAX1=INT(HMAX+.5):HMIN1=INT(HMIN2-.5)
6030 YY=CINT(TAH(8,1)+.5)
6040 YFACT=(1300/(HMAX1-HMIN1)):XFACT=800/YY
6050 PRINT #1,";: A H " 'INITIALIZE PLOTTER
6060 PRINT #1,"U 0,0 D 0,0 0,2200 1700,2200 1700,0 0,0 "
6070 PRINT #1,"U 300,200 D 300,200 300,2000 1500,2000 1500,200 300,200 "
6080 PRINT #1, "U 550,1940 S11+ MAXIMUM ADVANCE AS A FUNCTION OF HEIGHT
6090 PRINT #1, "U 730,1905 S11+ FOR THE TERRACE CUT _ "
6100 PRINT #1, "U 750,1845 S12 " NAME1$ " _ "
6140 FOR K=0 TO YY STEP 1
6150 X$=STR$(INT(K*XFACT+500.5)):YY$="460":HMIN$="450"
6160 IF K=0 THEN PRINT #1," U "X$","HMIN$
6170 PRINT #1, " D "X$","HMIN$
6180 PRINT #1, " D "X$","YY$
6190 PRINT #1, " D "X$","HMIN$
6200 NEXT K
6210 FOR K=0 TO YY STEP 1
6220 X$=STR$(INT(K*XFACT+460.5)):XX$=STR$(K):Y$="420.5"
6230 PRINT #1," U "X$","Y$" S11+ "XX$" _ "
6240 NEXT K
6250 PRINT #1, " U 500,450 "
6260 FOR K=HMIN1 TO HMAX1 STEP 1
6270 X$="500":X1$="510":Y$=STR$(INT((K-HMIN1)*YFACT+450.5))
6280 PRINT #1, " D "X$","Y$
6290 PRINT #1, " D "X1$","Y$
6300 PRINT #1, " D "X$","Y$
6310 NEXT K
6320 FOR K=HMIN1 TO HMAX1 STEP 1
6330 X$="415":Y$=STR$(INT((K-HMIN1)*YFACT+450.5)):YY$=STR$(K)
6340 PRINT #1,"U "X$","Y$
6350 PRINT #1," S11+ "YY$" _"
6360 NEXT K
6370 PRINT #1,"U 800,380":PRINT #1," S11+ ADVANCE (M) _ "
6380 PRINT #1,"U 350,900":PRINT #1," S41+ BENCH HEIGHT (M) _ "
6390 PRINT #1," EL "
```

```
6400 FOR I=2 TO 8
6410 IF I=2 THEN PRINT #1,"L0 "
6420 IF I=3 THEN PRINT #1,"L2 "
6430 IF I=4 THEN PRINT #1,"L4 "
6440 IF I=5 THEN PRINT #1,"L6 "
6450 IF I=6 THEN PRINT #1,"L8 "
6460 IF I=7 THEN PRINT #1,"L9 "
6470 IF I=8 THEN PRINT #1,"L: "
6480 FOR J=1 TO ICOUNT
6490 X$=STR$(INT(TAH(I,J)*XFACT+500.5)):Y$=STR$(INT((TAH(1,J)-HMIN1)*YFACT+450.5))
6500 IF J=1 THEN PRINT #1,"U "X$,Y$" "
6510 IF TAH(I,J)=0! THEN PRINT #1, "U "X$,Y$" "
6520 IF TAH(I,J)=0! GOTO 6540
6530 PRINT #1,"D " X$","Y$" "
6540 NEXT J:NEXT I
6541 PRINT #1,"L0 U 550,320 D 650,320 "
6542 PRINT #1,"L2 U 800,320 D 900,320 "
6543 PRINT #1,"L4 U 1050,320 D 1150,320 "
6544 PRINT #1,"L6 U 550,290 D 650,290 "
6545 PRINT #1,"L8 U 800,290 D 900,290 "
6546 PRINT #1,"L9 U 1050,290 D 1150,290 "
6547 PRINT #1,"L: U 550,260 D 650,260 "
6565 PRINT #1,"EL "
6566 PRINT #1,"L0 "
6570 PRINT #1," U 400,290 S11+ LEGEND _"
6580 PRINT #1," U 670,320 S11 FSA=30 _ "
6590 PRINT #1," U 920,320 S11 FSA=40 _ "
6600 PRINT #1," U 1170,320 S11 FSA=50 _ "
6610 PRINT #1," U 670,290 S11 FSA=60 _ "
6620 PRINT #1," U 920,290 S11 FSA=70 _ "
6630 PRINT #1," U 1170,290 S11 FSA=80 _ "
6640 PRINT #1," U 670,260 S11 FSA=89 _ "
6660 PRINT #1, "U 550,230 S11 FSA=FRONT SLOPE ANGLE _ "
6670 PRINT #1," H ":CLOSE
6680 RETURN
7000 FOR IJKL=0 TO 1000:NEXT IJKL:RESUME
```

APPENDIX 1-2

```
LOAD"B:TRMNSSA.BAS
Ok
RUN
NAME OF BWE? O&K SH  630
DIGGING WHEEL DIAMETER? 8.4
LENGTH OF BWE LOAD BOOM? 14.35
MAXIMUM LIFT OF DIGGING WHEEL CENTRE? 13.3
THE DISTANCE 'E'? -1.1
ELEVATION OF LOAD BOOM PIVOT POINT? 8.15
HORIZONTAL WHEEL FREE ANGLE ON SLOPE SIDE? 56
DO YOU WISH A PLOT OF THE DATA Y/N ? N
DO YOU WANT TO CHANGE THE HORIZ. WHEEL FREE ANGLE, (Y/N)? N
Ok




1LIST   2RUN  3LOAD"  4SAVE"  5CONT 6,"LPT1 7TRON 8TROFF9KEY    0SCREEN
```

```
10 DIM TATA(7,40)
20 PI=3.141593
30 INPUT "NAME OF BWE";NAME1$
40 INPUT "DIGGING WHEEL DIAMETER";D
50 INPUT "LENGTH OF BWE LOAD BOOM";LB
60 INPUT "MAXIMUM LIFT OF DIGGING WHEEL CENTRE";HM
70 INPUT "THE DISTANCE 'E'";E
80 INPUT "ELEVATION OF LOAD BOOM PIVOT POINT";Y
90 INPUT "HORIZONTAL WHEEL FREE ANGLE ON SLOPE SIDE";HWFA
100 MNSL=90-HWFA
110 IF MNSL>30 THEN N=30
120 IF MNSL>40 THEN N=40
130 IF MNSL>50 THEN N=50
170 MNSLR=MNSL*PI/180
180 LPRINT " "
190 LPRINT "MINIMUM OVERALL SIDE SLOPE ANGLE AS A FUNCTION OF HEIGHT FOR THE ";NAME1$
200 LPRINT " "
210 LPRINT "NOTE: MINIMUM SLEW ANGLE IS";MNSL
220 LPRINT "SL IS THE MAXIMUM SLEW ANGLE ON THE SLOPE SIDE"
230 LPRINT "NOTE: FOR TERRACE CUT"
240 LPRINT " "
250 LPRINT "HEIGHT     SL=90     SL=80     SL=70     SL=60     SL=50     SL=40"
260 BTAD=(Y-(D/2))/LB
270 BTDR=ATN(BTAD/SQR(1-BTAD*BTAD))
280 HHMAX%=(HM+(.2*D))/.5
290 HMAX=HHMAX%*.5
300 HHMIN%=(D/2)/.5
305 HMIN=HHMIN%*.5
310 HMIN2=HMIN
311 IF HMIN<(D/2) THEN GOTO 312 ELSE GOTO 320
312 HMIN=HMIN+.5
313 GOTO 311
320 H=HMIN
325 J%=1
330 I%=1
331 J=1
335 ICOUNT=(HMAX-HMIN)*2+1 'THIS WILL SET PLOT PARAMETERS
340 IF H>HMAX GOTO 550
350 I=2
360 IF H>HM THEN BTAH=(HM-Y)/LB
370 IF (H<=HM) AND (H>Y) THEN BTAH=(H-Y)/LB
380 IF (H<=Y) AND (H>=(D/2)) THEN BTAH=(Y-H)/LB
390 IF H>HM THEN H1=HM ELSE H1=H
400 BTHR=ATN(BTAH/SQR(1-BTAH*BTAH))
410 SL=90
420 SLR=SL*PI/180
430 A=(LB*COS(BTHR)-E+(D/2))*SIN(SLR)
440 B=(LB*COS(BTDR)-E)*SIN(MNSLR)
450 C=H1/(A-B)
460 TATA(I,J)=ATN(C)
470 TATA(I,J)=TATA(I,J)*180/PI
480 I=I+1
490 SL=SL-10
500 IF SL>N GOTO 420
```

```
502 IF N=50 THEN TATA(6,J)=0!
504 IF N=40 THEN TATA(7,J)=0!
506 IF N=50 THEN TATA(7,J)=0!
507 TATA(1,J)=H
510 LPRINT USING "###.##   ";TATA(1,J),TATA(2,J),TATA(3,J),TATA(4,J),TATA(5,J),TATA(6,J),TATA(7,J)
520 H=H+.5
525 J=J+1
530 I=2
540 GOTO 340
550 INPUT "DO YOU WISH A PLOT OF THE DATA Y/N ";Y$
560 IF Y$="Y" THEN GOSUB 5000
570 INPUT "DO YOU WANT TO CHANGE THE HORIZ. WHEEL FREE ANGLE, (Y/N)";Z$
580 IF Z$="Y" GOTO 90
590 END
5000 OPEN "COM2:2400,E,7,2,CS60000,DS60000" AS #1
5005 ON ERROR GOTO 6000
5010 HMAX1=INT(HMAX+.5):HMIN1=INT(HMIN2-.5)
5020 YFACT=(1300/(HMAX1-HMIN1)):XFACT=80/9
5040 PRINT #1,";: A H " 'INITIALIZE PLOTTER
5050 PRINT #1,"U 0,0 D 0,0 0,2200 1700,2200 1700,0 0,0 "
5055 PRINT #1,"U 300,200 D 300,200 300,2000 1500,2000 1500,200 300,200 "
5060 PRINT #1, "U 400,1940 S11+ MINIMUM OVERALL SIDE SLOPE ANGLE AS A FUNCTION OF HEIGHT _ "
5065 PRINT #1, "U 730,1905 S11+ FOR THE TERRACE CUT _ "
5070 PRINT #1, "U 750,1845 S12 " NAME1$ " _ "
5073 MNSL$=STR$(MNSL)
5075 PRINT #1, "U 550,1790 S11 MINIMUM SLEW ANGLE IS " MNSL$ " _ "
5080 FOR K=0 TO 90 STEP 10
5100 X$=STR$(INT(K*XFACT+500.5)):YY$="460":HMIN$="450"
5110 IF K=0 THEN PRINT #1," U "X$","HMIN$
5120 PRINT #1, " D "X$","HMIN$
5140 PRINT #1, " D "X$","YY$
5160 PRINT #1, " D "X$","HMIN$
5170 NEXT K
5180 FOR K=0 TO 90 STEP 10
5185 X$=STR$(INT(K*XFACT+460.5)):XX$=STR$(K):Y$="420.5"
5190 PRINT #1," U "X$","Y$" S11+ "XX$" _ "
5195 NEXT K
5200 PRINT #1, " U 500,450 "
5220 FOR K=HMIN1 TO HMAX1 STEP 1
5240 X$="500":X1$="510":Y$=STR$(INT((K-HMIN1)*YFACT+450.5))
5260 PRINT #1, " D "X$","Y$
5280 PRINT #1, " D "X1$","Y$
5300 PRINT #1, " D "X$","Y$
5320 NEXT K
5330 FOR K=HMIN1 TO HMAX1 STEP 1
5332 X$="415":Y$=STR$(INT((K-HMIN1)*YFACT+450.5)):YY$=STR$(K)
5334 PRINT #1,"U "X$","Y$
5336 PRINT #1," S11+ "YY$" _"
5338 NEXT K
5340 PRINT #1,"U 750,380":PRINT #1," S11+ SIDE SLOPE ANGLE  _ "
5350 PRINT #1,"U 350,900":PRINT #1," S41+ BENCH HEIGHT (M)  _ "
5355 PRINT #1," EL "
5360 FOR I=2 TO 7
5365 IF I=2 THEN PRINT #1,"L0 "
```

```
5366 IF I=3 THEN PRINT #1,"L3 "
5367 IF I=4 THEN PRINT #1,"L5 "
5368 IF I=5 THEN PRINT #1,"L7 "
5369 IF I=6 THEN PRINT #1,"L9 "
5370 IF I=7 THEN PRINT #1,"L: "
5380 FOR J=1 TO ICOUNT
5400 X$=STR$(INT(TATA(I,J)*XFACT+500.5)):Y$=STR$(INT((TATA(1,J)-HMIN1)*YFACT+450.5))
5420 IF J=1 THEN PRINT #1,"U "X$,Y$" "
5440 PRINT #1,"D " X$","Y$" "
5460 NEXT J:NEXT I
5461 PRINT #1,"L0 U 550,320 D 650,320 "
5462 PRINT #1,"L3 U 800,320 D 900,320 "
5463 PRINT #1,"L5 U 1050,320 D 1150,320 "
5464 PRINT #1,"L7 U 550,290 D 650,290 U "
5465 PRINT #1,"L9 U 800,290 D 900,290 U "
5466 PRINT #1,"L: U 1050,290 D 1150,290 "
5469 PRINT #1,"EL "
5470 PRINT #1,"L0 "
5480 PRINT #1," U 400,290 S11+ LEGEND _"
5488 PRINT #1," U 670,320 S11 MXSL=90 _ "
5489 PRINT #1," U 920,320 S11 MXSL=80 _ "
5490 PRINT #1," U 1170,320 S11 MXSL=70 _ "
5491 PRINT #1," U 670,290 S11 MXSL=60 _ "
5492 PRINT #1," U 920,290 S11 MXSL=50 _ "
5493 PRINT #1," U 1170,290 S11 MXSL=40 _ "
5495 PRINT #1,"L0 "
5496 PRINT #1, "U 550,260 S11 MXSL=MAXIMUM SLEW ANGLE _ "
5499 PRINT #1," H ":CLOSE
5500 RETURN
6000 FOR IJKL=0 TO 1000:NEXT IJKL:RESUME
```

APPENDIX I-3

```
LOAD"B:TRCUTW.BAS
Ok
RUN
NAME OF BWE? O&K SH 630
DIGGING WHEEL DIAMETER? 8.4
LENGTH OF BWE LOAD BOOM? 14.35
MAXIMUM LIFT OF DIGGING WHEEL CENTRE? 13.3
THE DISTANCE 'E'? -1.1
THE ELEVATION OF THE LOAD BOOM PIVOT POINT? 8.15
MAXIMUM HORIZONTAL WHEEL FREE ANGLE ON THE SLOPE SIDE? 56
MAXIMUM SLEW ANGLE ON OPEN SIDE AT GROUND LEVEL? 30
MAXIMUM SLEW ANGLE ON TOP TERRACE ON SIDE SLOPE SIDE? 70
DO YOU WANT TO PLOT THE DATA, (Y/N)? N
DO YOU WANT TO CHANGE MAXIMUM SLEW ANGLES, (Y/N)? Y
MAXIMUM SLEW ANGLE ON OPEN SIDE AT GROUND LEVEL? 30
MAXIMUM SLEW ANGLE ON TOP TERRACE ON SIDE SLOPE SIDE? 90
DO YOU WANT TO PLOT THE DATA, (Y/N)? N
DO YOU WANT TO CHANGE MAXIMUM SLEW ANGLES, (Y/N)? N
Ok



1LIST   2RUN   3LOAD"   4SAVE"   5CONT 6,"LPT1 7TRON 8TROFF9KEY    0SCREEN
```

```
10 DIM W(8,40)
20 PI=3.141593
30 INPUT "NAME OF BWE";NAME1$
40 INPUT "DIGGING WHEEL DIAMETER";D
50 INPUT "LENGTH OF BWE LOAD BOOM";LB
60 INPUT "MAXIMUM LIFT OF DIGGING WHEEL CENTRE";HM
70 INPUT "THE DISTANCE 'E'";E
80 INPUT "THE ELEVATION OF THE LOAD BOOM PIVOT POINT";Y
90 INPUT "MAXIMUM HORIZONTAL WHEEL FREE ANGLE ON THE SLOPE SIDE";HWFA
100 MNSL=90-HWFA
110 I%=1
120 NMSLR=MNSL*PI/180
130 INPUT "MAXIMUM SLEW ANGLE ON OPEN SIDE AT GROUND LEVEL";OSSA
140 INPUT "MAXIMUM SLEW ANGLE ON TOP TERRACE ON SIDE SLOPE SIDE";PSSA
150 IF PSSA(MNSL GOTO 630
160 PSSAR=PSSA*PI/180
170 OSSAR=OSSA*PI/180
175 MNSLR=MNSL*PI/180
180 LPRINT " "
190 LPRINT "WIDTH OF CUT AS A FUNCTION OF HEIGHT AND SIDE SLOPE ANGLE FOR THE ";NAME1$
200 LPRINT " "
210 LPRINT "NOTE: MAXIMUM SLEW ANGLE FOR THE TOP TERRACE ON SIDE SLOPE SIDE IS";PSSA
220 LPRINT "NOTE: MAXIMUM SLEW ANGLE ON THE OPEN SIDE IS";OSSA
230 LPRINT "'W' IS THE CUT WIDTH @ THE SIDE SLOPE ANGLE FOR THE TERRACE CUT"
240 LPRINT "MINIMUM SLEW ANGLE IS ";MNSL
245 LPRINT "TERRACE CUT"
250 LPRINT "HEIGHT      W@30     W@40     W@50     W@60     W@70     W@80     W@89"
260 BTAD=(Y-(D/2))/LB
270 BTDR=ATN(BTAD/SQR(1-BTAD*BTAD))
280 HHMAX%=(HM+(.2*D))/.5
290 HMAX=HHMAX%*.5
300 HHMIN%=(D/2)/.5
305 HMIN=HHMIN%*.5
310 HMIN2=HMIN
311 IF HMIN((D/2) THEN GOTO 312 ELSE GOTO 315
312 HMIN=HMIN+.5
313 GOTO 311
315 ICOUNT=(HMAX-HMIN)*2+1
320 H=HMIN
325 J%=1
326 J=1
330 I=2
340 W(I,J)=99!
350 I=I+1
360 IF I(9 GOTO 340
370 IF H)HMAX GOTO 592
380 I=2
390 SS=30
400 SSR=SS*PI/180
410 IF H)HM THEN BTAH=(HM-Y)/LB
420 IF (H(=HM) AND (H)Y) THEN BTAH=(H-Y)/LB
430 IF (H(=Y) AND (H)=(D/2)) THEN BTAH=(Y-H)/LB
440 BTHR=ATN(BTAH/SQR(1-BTAH*BTAH))
450 A=(LB*COS(BTHR)-E+(D/2))*SIN(PSSAR)
```

```
452 A1=(LB*COS(BTDR)-E)*SIN(MNSLR)
455 L1A=A-A1
460 B=(LB*COS(BTDR)-E)*SIN(OSSAR)
470 C=H/TAN(SSR)
480 IF C)L1A THEN WI=0!
490 IF C)L1A GOTO 510
500 WI=A+B-C
510 IF WI(0! THEN WI=0!
520 W(I,J)=WI
530 I=I+1
540 SS=SS+10
550 IF SS=90 THEN SS=89
560 IF SS(90 GOTO 400
565 W(1,J)=H
570 LPRINT USING "###.##   ";W(1,J),W(2,J),W(3,J),W(4,J),W(5,J),W(6,J),W(7,J),W(8,J)
575 J=J+1
580 H=H+.5
590 GOTO 370
59[illegible] [illegible] W(8,1)
59[illegible] [illegible] "DO YOU WANT TO PLOT THE DATA, (Y/N)";ZZ$
596 IF ZZ$="Y" THEN GOSUB 5000
600 INPUT "DO YOU WANT TO CHANGE MAXIMUM SLEW ANGLES, (Y/N)";Z$
610 IF Z$="Y" GOTO 130
620 GOTO 650.
630 PRINT "SLEW ANGLE IS LESS THAN THE MINIMUM ANGLE"
640 GOTO 600
650 END
5000 OPEN "COM2:2400,E,7,2,CS60000,DS60000" AS #1
5005 ON ERROR GOTO 6000
5010 HMAX1=INT(HMAX+.5):HMIN1=INT(HMIN2-.5)
5015 YY=CINT(YMAX+.5):YYY=INT(A1+B)
5017 IF YY/2 )( INT(YY/2) THEN YY=YY+1
5018 IF YYY/2 )( INT(YYY/2) THEN YYY=YYY-1
5020 YFACT=(1300/(HMAX1-HMIN1)):XFACT=800/(YY-YYY)
5040 PRINT #1,";: A H " 'INITIALIZE PLOTTER
5050 PRINT #1,"U 0,0 D 0,0 0,2200 1700,2200 1700,0 0,0 "
5055 PRINT #1,"U 300,200 D 300,200 300,2000 1500,2000 1500,200 300,200 "
5060 PRINT #1, "U 500,1940 S11+ WIDTH OF CUT AS A FUNCTION OF BENCH HEIGHT _ "
5065 PRINT #1, "U 680,1905 S11+ FOR THE TERRACE CUT _ "
5070 PRINT #1, "U 750,1845 S12 " NAME1$ " _ "
5072 MXSL$=STR$(PSSA):MNSL$=STR$(MNSL):OSSA$=STR$(OSSA)
5075 PRINT #1, "U 370,1790 S11 MINIMUM SLEW ANGLE IS " MNSL$ " _ "
5077 PRINT #1, "U 720,1790 S11 MAX SLEW ANGLE SLOPE SIDE " MXSL$ " _ "
5078 PRINT #1, "U 1110,1790 S11 MAX SLEW ANGLE PIT SIDE " OSSA$ " _ "
5080 FOR K=0 TO (YY-YYY) STEP 2
5100 X$=STR$(INT(K*XFACT+500.5)):YY$="460":HMIN$="450"
5110 IF K=0 THEN PRINT #1," U "X$","HMIN$
5120 PRINT #1, " D "X$","HMIN$
5140 PRINT #1, " D "X$","YY$
5160 PRINT #1, " D "X$","HMIN$
5170 NEXT K
5180 FOR K=0 TO (YY-YYY) STEP 2
5185 X$=STR$(INT(K*XFACT+460.5)):XX$=STR$(K+YYY):Y$="420.5"
5190 PRINT #1," U "X$","Y$" S11+ "XX$" _ "
```

```
5195 NEXT K
5200 PRINT #1, " U 500,450 "
5220 FOR K=HMIN1 TO HMAX1 STEP 1
5240 X$="500":X1$="510":Y$=STR$(INT((K-HMIN1)*YFACT+450.5))
5260 PRINT #1, " D "X$","Y$
5280 PRINT #1, " D "X1$","Y$
5300 PRINT #1, " D "X$","Y$
5320 NEXT K
5330 FOR K=HMIN1 TO HMAX1 STEP 1
5332 X$="415":Y$=STR$(INT((K-HMIN1)*YFACT+450.5)):YY$=STR$(K)
5334 PRINT #1,"U "X$","Y$
5336 PRINT #1," S11+ "YY$" _"
5338 NEXT K
5340 PRINT #1,"U 800,380":PRINT #1," S11+ WIDTH OF CUT (M) _ "
5350 PRINT #1,"U 350,900":PRINT #1," S41+ BENCH HEIGHT (M) _ "
5355 PRINT #1," EL "
5360 FOR I=2 TO 8
5365 IF I=2 THEN PRINT #1,"L0 "
5366 IF I=3 THEN PRINT #1,"L2 "
5367 IF I=4 THEN PRINT #1,"L4 "
5368 IF I=5 THEN PRINT #1,"L6 "
5369 IF I=6 THEN PRINT #1,"L8 "
5370 IF I=7 THEN PRINT #1,"L9 "
5375 IF I=8 THEN PRINT #1,"L: "
5380 FOR J=1 TO ICOUNT
5400 X$=STR$(INT(W(I,J)*XFACT+500.5-(XFACT*YYY)))
5410 Y$=STR$(INT((W(1,J)-HMIN1)*YFACT+450.5))
5420 IF J=1 THEN PRINT #1,"U "X$,Y$" "
5423 IF W(I,J)=0! THEN PRINT #1, "U "X$,Y$" "
5426 IF W(I,J)=0! GOTO 5460
5440 PRINT #1,"D " X$","Y$" "
5460 NEXT J:NEXT I
5461 PRINT #1,"L0 U 550,320 D 650,320 "
5462 PRINT #1,"L2 U 800,320 D 900,320 "
5463 PRINT #1,"L4 U 1050,320 D 1150,320 "
5464 PRINT #1,"L6 U 550,290 D 650,290 "
5465 PRINT #1,"L8 U 800,290 D 900,290 "
5466 PRINT #1,"L9 U 1050,290 D 1150,290 "
5467 PRINT #1,"L: U 550,260 D 650,260 "
5475 PRINT #1,"EL "
5476 PRINT #1,"L0 "
5480 PRINT #1," U 400,290 S11+ LEGEND _"
5488 PRINT #1," U 670,320 S11 SSA=30 _ "
5489 PRINT #1," U 920,320 S11 SSA=40 _ "
5490 PRINT #1," U 1170,320 S11 SSA=50 _ "
5491 PRINT #1," U 670,290 S11 SSA=60 _ "
5492 PRINT #1," U 920,290 S11 SSA=70 _ "
5493 PRINT #1," U 1170,290 S11 SSA=80 _ "
5494 PRINT #1," U 670,260 S11 SSA=89 _ "
5497 PRINT #1, "U 550,230 S11 SSA=SIDE SLOPE ANGLE _ "
5499 PRINT #1," H ":CLOSE
5500 RETURN
6000 FOR IJKL=0 TO 1000:NEXT IJKL:RESUME
```

APPENDIX I-4

```
LOAD"B:DRFSA.BAS
Ok
RUN
NAME OF BWE? O&K SH 630
DIGGING WHEEL DIAMETER? 8.4
LENGTH OF BWE LOAD BOOM? 14.35
MAXIMUM LIFT OF DIGGING WHEEL CENTRE? 13.3
THE DISTANCE 'E'? -1.1
ELEVATION OF LOAD BOOM PIVOT POINT? 8.15
MINIMUM SLOPE HEIGHT? 4
DISTANCE BETWEEN LATERAL CENTER LINE AND FRONT EDGE OF CRAWLER, IE. CL? 4.65
DISTANCE BETWEEN CENTRE LINE OF ADVANCE AND OUTSIDE EDGE OF CRAWLER, IE. CW? 4.9
5
DO YOU WANT TO PLOT THE DATA, (Y/N)? N
DO YOU WANT CALCULATIONS FOR ADVANCE AS A FUNCTION OF HEIGHT AND SLOPE ANGLE, (Y
/N)? Y
DO YOU WANT TO PLOT THE DATA, (Y/N)? N
Ok




1LIST   2RUN   3LOAD"   4SAVE"   5CONT 6,"LPT1 7TRON 8TROFF9KEY    0SCREEN
```

```
10 DIM TAH(9,40)
20 PI=3.141593
30 INPUT "NAME OF BWE";NAME1$
40 INPUT "DIGGING WHEEL DIAMETER";D
50 INPUT "LENGTH OF BWE LOAD BOOM";LB
60 INPUT "MAXIMUM LIFT OF DIGGING WHEEL CENTRE";HM
70 INPUT "THE DISTANCE 'E'";E
80 INPUT "ELEVATION OF LOAD BOOM PIVOT POINT";Y
90 INPUT "MINIMUM SLOPE HEIGHT";HMIN
100 INPUT "DISTANCE BETWEEN LATERAL CENTER LINE AND FRONT EDGE OF CRAWLER, IE. CL";CL
110 INPUT "DISTANCE BETWEEN CENTRE LINE OF ADVANCE AND OUTSIDE EDGE OF CRAWLER, IE. CW";CW
120 LPRINT "OVERALL MINIMUM FRONT SLOPE AS A FUNCTION OF HEIGHT AND ADVANCE FOR THE ";NAME1$
130 LPRINT " "
140 LPRINT "'A' IS ADVANCE AND CALCULATED NUMBERS ARE FRONT SLOPE ANGLE"
150 LPRINT "NOTE: FOR DROPPING CUT"
160 LPRINT "HEIGHT    A=1      A=2      A=3      A=4      A=5      A=6      A=7      A=8"
170 BTAD=(Y-(.5*D))/LB
180 BTDR=ATN(BTAD/SQR(1-BTAD*BTAD))
190 F1=LB*COS(BTDR)-E
200 F2=((F1^2)-(CW^2))^.5
210 F=1+(F1-F2)
212 N=D
215 HHT%=(HM-(D/2))/.1:HT=HHT%*.1
220 H=HMIN
230 HHMAX%=(HM+(.2*D))/.5
235 HMAX=HHMAX%*.5
240 I%=1
242 ICOUNT=(HMAX-HMIN)*2+1
244 J%=1
246 J=1
250 IF H)HMAX GOTO 470
260 A=1
270 I=2
280 H1=H+(D/2)
290 IF H1)HM THEN BTAH=(HM-Y)/LB
300 IF (H1(=HM) AND (H1)Y) THEN BTAH=(H1-Y)/LB
310 IF (H1(=Y) AND (H1)=(D/2)) THEN BTAH=(Y-H1)/LB
350 BTHR=ATN(BTAH/SQR(1-BTAH*BTAH))
355 IF A)N THEN TAH(I,J)=0!
356 IF A)N GOTO 410
360 AA=(LB*COS(BTHR)-E)-(A+F+CL)
370 IF AA(=0! THEN TAH(I,J)=90!
380 IF AA(=0! GOTO 410
390 IF H(HT THEN TAH(I,J)=ATN(H/AA) ELSE TAH(I,J)=ATN(HT/AA)
400 TAH(I,J)=TAH(I,J)*180/PI
410 I=I+1
420 A=A+1
430 IF A(9 GOTO 355
435 TAH(1,J)=H
440 LPRINT USING "###.##  ";TAH(1,J),TAH(2,J),TAH(3,J),TAH(4,J),TAH(5,J),TAH(6,J),TAH(7,J),TAH(8,J),TAH(9,J)
450 H=H+.5
455 J=J+1
460 GOTO 250
470 LPRINT " "
```

```
480 HHT%=(HM-(D/2))/.1
485 HT=HHT%*.1
490 LPRINT "TERRACE CUT ABOVE BENCH HEIGHT OF ";HT
492 INPUT "DO YOU WANT TO PLOT THE DATA, (Y/N)";ZZ$
494 IF ZZ$="Y" THEN GOSUB 5000
500 INPUT "DO YOU WANT CALCULATIONS FOR ADVANCE AS A FUNCTION OF HEIGHT AND SLOPE ANGLE, (Y/N)";Z$
510 IF Z$="N" GOTO 880
520 LPRINT " "
530 LPRINT "ADVANCE AS A FUNCTION OF HEIGHT AND FRONT SLOPE ANGLE FOR THE ";NAME1$
540 LPRINT " "
550 LPRINT "'A' IS ADVANCE @ FRONT SLOPE ANGLE"
560 LPRINT "NOTE: FOR DROPPING CUT"
570 LPRINT "HEIGHT     A@30     A@40     A@50     A@60     A@70     A@80     A@89"
580 H=HMIN
585 J=1
590 I=2
600 TAH(I,J)=99!
610 I=I+1
620 IF I<10 GOTO 600
630 IF H>HMAX GOTO 870
640 FSA=30
650 I=2
660 FSAR=FSA*PI/180
670 H1=H+(D/2)
680 IF H1>HM THEN BTAH=(HM-Y)/LB
690 IF (H1<=HM) AND (H1>Y) THEN BTAH=(H1-Y)/LB
700 IF (H1<=Y) AND (H1>=HMIN) THEN BTAH=(Y-H1)/LB
740 BTHR=ATN(BTAH/SQR(1-BTAH*BTAH))
750 IF H>HT THEN AA=HT/TAN(FSAR) ELSE AA=H/TAN(FSAR)
760 BB=LB*COS(BTHR)-E
770 TAHI=BB-AA-CL-F
780 IF TAHI<0! THEN TAHI=0!
785 IF TAHI>D THEN TAHI=D
790 TAH(I,J)=TAHI
800 I=I+1
810 FSA=FSA+10
820 IF FSA=90 THEN FSA=89
830 IF FSA<90 GOTO 660
840 LPRINT USING "###.##  ";TAH(1,J),TAH(2,J),TAH(3,J),TAH(4,J),TAH(5,J),TAH(6,J),TAH(7,J),TAH(8,J)
850 H=H+.5
855 J=J+1
860 GOTO 630
865 YMAX=TAH(8,1)
870 LPRINT " "
880 LPRINT "TERRACE CUT ABOVE BENCH HEIGHT OF ";HT
882 INPUT "DO YOU WANT TO PLOT THE DATA, (Y/N)";ZZ$
884 IF ZZ$="Y" THEN GOSUB 6000
890 END
5000 OPEN "COM2:2400,E,7,2,CS60000,DS60000" AS #1
5005 ON ERROR GOTO 5900
5010 HMAX1=INT(HMAX+.5):HMIN1=INT(HMIN-.5)
5020 YFACT=(1300/(HMAX1-HMIN1)):XFACT=80/9
5030 PRINT #1,";: A H " 'INITIALIZE PLOTTER
5040 PRINT #1,"U 0,0 D 0,0 0,2200 1700,2200 1700,0 0,0 "
```

```
5050 PRINT #1,"U 300,200 D 300,200 300,2000 1500,2000 1500,200 300,200 "
5060 PRINT #1, "U 400,1940 S11+ MINIMUM OVERALL FRONT SLOPE ANGLE AS A FUNCTION OF HEIGHT _ "
5065 PRINT #1, "U 730,1905 S11+ FOR THE DROPPING CUT _ "
5070 PRINT #1, "U 750,1845 S12 " NAME1$ " _ "
5080 FOR K=0 TO 90 STEP 10
5090 X$=STR$(INT(K*XFACT+500.5)):YY$="460":HMIN$="450"
5100 IF K=0 THEN PRINT #1," U "X$","HMIN$
5110 PRINT #1, " D "X$","HMIN$
5120 PRINT #1, " D "X$","YY$
5130 PRINT #1, " D "X$","HMIN$
5140 NEXT K
5150 FOR K=0 TO 90 STEP 10
5160 X$=STR$(INT(K*XFACT+460.5)):XX$=STR$(K):Y$="420.5"
5170 PRINT #1," U "X$","Y$" S11+ "XX$" _ "
5180 NEXT K
5190 PRINT #1, " U 500,450 "
5200 FOR K=HMIN1 TO HMAX1 STEP 1
5210 X$="500":X1$="510":Y$=STR$(INT((K-HMIN1)*YFACT+450.5))
5220 PRINT #1, " D "X$","Y$
5230 PRINT #1, " D "X1$","Y$
5240 PRINT #1, " D "X$","Y$
5250 NEXT K
5260 FOR K=HMIN1 TO HMAX1 STEP 1
5270 X$="415":Y$=STR$(INT((K-HMIN1)*YFACT+450.5)):YY$=STR$(K)
5280 PRINT #1,"U "X$","Y$
5290 PRINT #1," S11+ "YY$" _"
5300 NEXT K
5310 PRINT #1,"U 800,380":PRINT #1," S11+ FRONT SLOPE ANGLE  _ "
5320 PRINT #1,"U 350,900":PRINT #1," S41+ BENCH HEIGHT (M) _ "
5330 PRINT #1," EL "
5340 FOR I=2 TO 9
5350 IF I=2 THEN PRINT #1,"L0 "
5360 IF I=3 THEN PRINT #1,"L1 "
5370 IF I=4 THEN PRINT #1,"L3 "
5380 IF I=5 THEN PRINT #1,"L5 "
5390 IF I=6 THEN PRINT #1,"L7 "
5400 IF I=7 THEN PRINT #1,"L8 "
5402 IF I=8 THEN PRINT #1,"L9 "
5404 IF I=9 THEN PRINT #1,"L: "
5410 FOR J=1 TO ICOUNT
5420 X$=STR$(INT(TAH(I,J)*XFACT+500.5)):Y$=STR$(INT((TAH(1,J)-HMIN1)*YFACT+450.5))
5430 IF J=1 THEN PRINT #1,"U "X$,Y$" "
5440 PRINT #1,"D " X$","Y$" "
5450 NEXT J:NEXT I
5455 PRINT #1,"L0 U 550,320 D 650,320 "
5456 PRINT #1,"L1 U 800,320 D 900,320 "
5457 PRINT #1,"L3 U 1050,320 D 1150,320 "
5458 PRINT #1,"L5 U 550,290 D 650,290 "
5459 PRINT #1,"L7 U 800,290 D 900,290 "
5460 PRINT #1,"L8 U 1050,290 D 1150,290 "
5461 PRINT #1,"L9 U 550,260 D 650,260 "
5470 PRINT #1,"L: U 800,260 D 900,260 "
5475 PRINT #1,"EL "
5476 PRINT #1,"L0 "
```

```
5480 PRINT #1," U 400,290 S11+ LEGEND _"
5490 PRINT #1," U 670,320 S11 A=1 _ "
5500 PRINT #1," U 920,320 S11 A=2 _ "
5510 PRINT #1," U 1170,320 S11 A=3 _ "
5520 PRINT #1," U 670,290 S11 A=4 _ "
5530 PRINT #1," U 920,290 S11 A=5 _ "
5540 PRINT #1," U 1170,290 S11 A=6 _ "
5542 PRINT #1," U 670,260 S11 A=7 _ "
5544 PRINT #1," U 920,260 S11 A=8 _ "
5552 PRINT #1,"U 550,230 S11 A=ADVANCE _ "
5560 PRINT #1," H ":CLOSE
5570 RETURN
5900 FOR IJKL=0 TO 1000:NEXT IJKL:RESUME
6000 OPEN "COM2:2400,E,7,2,CS60000,DS60000" AS #1
6010 ON ERROR GOTO 7000
6020 HMAX1=INT(HMAX+.5):HMIN1=INT(HMIN-.5)
6030 YY=CINT(TAH(8,1)+.5)
6040 YFACT=(1300/(HMAX1-HMIN1)):XFACT=800/YY
6050 PRINT #1,";: A H " 'INITIALIZE PLOTTER
6060 PRINT #1,"U 0,0 D 0,0 0,2200 1700,2200 1700,0 0,0 "
6070 PRINT #1,"U 300,200 D 300,200 300,2000 1500,2000 1500,200 300,200 "
6080 PRINT #1, "U 550,1940 S11+ MAXIMUM ADVANCE AS A FUNCTION OF HEIGHT _ "
6090 PRINT #1, "U 730,1905 S11+ FOR THE DROPPING CUT _ "
6100 PRINT #1, "U 750,1845 S12 " NAME1$ " _ "
6140 FOR K=0 TO YY STEP 1
6150 X$=STR$(INT(K*XFACT+500.5)):YY$="460":HMIN$="450"
6160 IF K=0 THEN PRINT #1," U "X$","HMIN$
6170 PRINT #1, " D "X$","HMIN$
6180 PRINT #1, " D "X$","YY$
6190 PRINT #1, " D "X$","HMIN$
6200 NEXT K
6210 FOR K=0 TO YY STEP 1
6220 X$=STR$(INT(K*XFACT+460.5)):XX$=STR$(K):Y$="420.5"
6230 PRINT #1," U "X$","Y$" S11+ "XX$" _ "
6240 NEXT K
6250 PRINT #1, " U 500,450 "
6260 FOR K=HMIN1 TO HMAX1 STEP 1
6270 X$="500":X1$="510":Y$=STR$(INT((K-HMIN1)*YFACT+450.5))
6280 PRINT #1, " D "X$","Y$
6290 PRINT #1, " D "X1$","Y$
6300 PRINT #1, " D "X$","Y$
6310 NEXT K
6320 FOR K=HMIN1 TO HMAX1 STEP 1
6330 X$="415":Y$=STR$(INT((K-HMIN1)*YFACT+450.5)):YY$=STR$(K)
6340 PRINT #1,"U "X$","Y$
6350 PRINT #1," S11+ "YY$" _".
6360 NEXT K
6370 PRINT #1,"U 800,380":PRINT #1," S11+ ADVANCE (M) _ "
6380 PRINT #1,"U 350,900":PRINT #1," S41+ BENCH HEIGHT (M) _ "
6390 PRINT #1," EL "
6400 FOR I=2 TO 8
6410 IF I=2 THEN PRINT #1,"L0 "
6420 IF I=3 THEN PRINT #1,"L2 "
6430 IF I=4 THEN PRINT #1,"L4 "
```

```
6440 IF I=5 THEN PRINT #1,"L6 "
6450 IF I=6 THEN PRINT #1,"L8 "
6460 IF I=7 THEN PRINT #1,"L9 "
6470 IF I=8 THEN PRINT #1,"L: "
6480 FOR J=1 TO ICOUNT
6490 X$=STR$(INT(TAH(I,J)*XFACT+500.5)):Y$=STR$(INT((TAH(1,J)-HMIN1)*YFACT+450.5))
6500 IF J=1 THEN PRINT #1,"U "X$,Y$" "
6510 IF TAH(I,J)=0! THEN PRINT #1, "U "X$,Y$" "
6520 IF TAH(I,J)=0! GOTO 6540
6530 PRINT #1,"D " X$","Y$" "
6540 NEXT J:NEXT I
6545 PRINT #1,"L0 U 550,320 D 650,320 "
6546 PRINT #1,"L2 U 800,320 D 900,320 "
6547 PRINT #1,"L4 U 1050,320 D 1150,320 "
6548 PRINT #1,"L6 U 550,290 D 650,290 "
6549 PRINT #1,"L8 U 800,290 D 900,290 "
6550 PRINT #1,"L9 U 1050,290 D 1150,290 "
6560 PRINT #1,"L: U 550,260 D 650,260 "
6565 PRINT #1,"EL "
6566 PRINT #1,"L0 "
6570 PRINT #1," U 400,290 S11+ LEGEND _"
6580 PRINT #1," U 670,320 S11 FSA=30 _ "
6590 PRINT #1," U 920,320 S11 FSA=40 _ "
6600 PRINT #1," U 1170,320 S11 FSA=50 _ "
6610 PRINT #1," U 670,290 S11 FSA=60 _ "
6620 PRINT #1," U 920,290 S11 FSA=70 _ "
6630 PRINT #1," U 1170,290 S11 FSA=80 _ "
6640 PRINT #1," U 670,260 S11 FSA=89 _ "
6660 PRINT #1, "U 550,230 S11 FSA=SIDE SLOPE ANGLE _ "
6670 PRINT #1," H ":CLOSE
6680 RETURN
7000 FOR IJKL=0 TO 1000:NEXT IJKL:RESUME
```

APPENDIX 1-5

```
LOAD"B:MODELC.BAS
Ok
RUN
NAME OF BWE? O&K SH  630
DIGGING WHEEL DIAMETER TO OUTSIDE OF BUCKETS? 8.4
DIGGING WHEEL DIAMETER WITHOUT BUCKETS? 6.9
LENGTH OF BWE LOAD BOOM? 14.35
MAXIMUM LIFT OF DIGGING WHEEL CENTRE? 13.3
THE DISTANCE 'E'? -1.1
ELEVATION ON LOAD BOOM PIVOT POINT? 8.15
DISTANCE BETWEEN CENTRE LINE OF ADVANCE AND EDGE OF CRAWLERS, IE. CW? 4.95
MINIMUM BENCH HEIGHT? 4
SAFETY DISTANCE REQUIRED BETWEEN SLOPE TOES AND CRAWLERS? 1
VERTICAL WHEEL FREE ANGLE? 59
MAXIMUM SLEW ANGLE ON SLOPE SIDE? 70
DO YOU WANT TO PLOT THE DATA, (Y/N)? N
DO YOU WANT TO CHANGE THE MAXIMUM SLEW ANGLE ON THE SLOPE SIDE, (Y/N)? Y
MAXIMUM SLEW ANGLE ON SLOPE SIDE? 90
DO YOU WANT TO PLOT THE DATA, (Y/N)? N
DO YOU WANT TO CHANGE THE MAXIMUM SLEW ANGLE ON THE SLOPE SIDE, (Y/N)? N
DO YOU WANT TO CHANGE THE VERTICAL WHEEL FREE ANGLE, (Y/N)? N
Ok

1LIST   2RUN   3LOAD"   4SAVE"   5CONT 6,"LPT1 7TRON 8TROFF9KEY    0SCREEN
```

```
10 DIM SSA(7,40)
20 PI=3.141593
30 INPUT "NAME OF BWE";NAME1$
40 INPUT "DIGGING WHEEL DIAMETER TO OUTSIDE OF BUCKETS";D
45 INPUT "DIGGING WHEEL DIAMETER WITHOUT BUCKETS";D1
47 AB=(D-D1)/2
50 INPUT "LENGTH OF BWE LOAD BOOM";LB
60 INPUT "MAXIMUM LIFT OF DIGGING WHEEL CENTRE";HM
70 INPUT "THE DISTANCE 'E'";E
80 INPUT "ELEVATION ON LOAD BOOM PIVOT POINT";Y
90 INPUT "DISTANCE BETWEEN CENTRE LINE OF ADVANCE AND EDGE OF CRAWLERS, IE. CW";CW
100 INPUT "MINIMUM BENCH HEIGHT";HMIN
110 INPUT "SAFETY DISTANCE REQUIRED BETWEEN SLOPE TOES AND CRAWLERS";F
120 INPUT "VERTICAL WHEEL FREE ANGLE";VWFA
130 VWFAR=VWFA*PI/180
140 HHMAX%=(HM+(.2*D))/.5
150 HMAX=HHMAX%*.5
160 BTAD=(Y-(D/2))/LB
170 BTDR=ATN(BTAD/SQR(1-BTAD*BTAD))
180 MNSL=(CW+F)/(LB*COS(BTDR)-E)
190 MNSLR=ATN(MNSL/SQR(1-MNSL*MNSL))
220 INPUT "MAXIMUM SLEW ANGLE ON SLOPE SIDE";MXSL
230 I%=1:I=2
235 J%=1:J=1
238 HTT%=(HM-(D/2))/.1:HT=HTT%*.1
239 HS=HT+AB
240 SSA(I,J)=0!
250 I=I+1
260 IF I<=7 GOTO 240
270 MXSLR=MXSL*PI/180
275 IF MXSLR<MNSLR GOTO 1165
280 LPRINT " "
290 LPRINT "RANGE OF SIDE SLOPE ANGLES AS A FUNCTION OF HEIGHT FOR THE ";NAME1$
300 LPRINT " "
310 LPRINT "NOTE: DROPPING CUT, MODEL C
320 LPRINT "MAXIMUM SLEW ANGLE IS";MXSL
325 LPRINT "VERTICAL WHEEL FREE ANGLE IS ";VWFA
330 LPRINT "HEIGHT    MINSSA   MAXSSA"
340 H=HMIN
344 J=1
346 ICOUNT=(HMAX-HMIN)*2+1
350 IF H>HMAX GOTO 1095
360 IF H=0 GOTO 1035
375 SSA(2,J)=.1:SSA(3,J)=.1
380 HA=H+(D/2)
390 IF HA>HM THEN BTAH=(HM-Y)/LB
400 IF (HA<=HM) AND (HA>Y) THEN BTAH=(HA-Y)/LB
410 IF (HA<=Y) AND (HA>=(D/2)) THEN BTAH=(Y-HA)/LB
415 BTHR=ATN(BTAH/SQR(1-BTAH*BTAH))
453 A=(LB*COS(BTHR)-E)*SIN(MXSLR)
456 B=(LB*COS(BTDR)-E)*SIN(MNSLR)
459 SSAI=ATN(H/(A-B)):IF H>HT THEN SSAI=ATN(HT/(A-B))
462 SSAJ=SSAI*180/PI:SSAJ=90-SSAJ:SSAJ=SSAJ*PI/180
465 H1=(D/2)*SIN(SSAJ):R1=(D/2)*COS(SSAJ)
```

```
468 H2=(D/2)-AB-H1
471 IF H<(HS+H2) GOTO 489
474 IF H>HM GOTO 1037
477 RD=(((D/2)^2)-((HM-H)^2))^.5
480 A=(LB*COS(BTHR)-E+RD)*SIN(MXSLR)
483 B=(LB*COS(BTDR)-E+R1)*SIN(MNSLR)
486 SSAI=ATN(H/(A-B))
489 BTAD1=(Y-(D/2)-AB)/LB:BTDR1=ATN(BTAD1/SQR(1-BTAD1*BTAD1))
492 L1AB=AB/TAN(SSAI)
495 SLAB1=(LB*COS(BTDR)-E)*SIN(MNSLR)
498 SLAB2=(LB*COS(BTDR1)-E)
501 SLAB=(SLAB1+L1AB)/SLAB2:SLABR=ATN(SLAB/SQR(1-SLAB*SLAB))
504 YB=(LB*COS(BTDR1)-E)*SIN(SLABR)-SLAB1
507 XB=(LB*COS(BTDR)-E)*COS(MNSLR)-(LB*COS(BTDR1)-E)*COS(SLABR)
510 XYB=((XB^2)+(YB^2))^.5
513 L2AB=AB/TAN(VWFAR)
516 IF XYB<L2AB THEN SSA(2,J)=0! ELSE SSA(2,J)=SSAI*180/PI
518 IF XYB<L2AB THEN SSA(3,J)=0!
519 IF XYB<L2AB GOTO 1050
550 BTHR1=BTHR:L2AB1=L2AB:N=H/AB:KX=1:K=1:AB1=AB:SL1R=MXSLR:SLRT=MXSLR
560 HA=H+(D/2)-(AB1*K):IF (AB1*K)>H THEN HA=H+(D/2)-(N*AB1)
562 IF (AB1*K)>H THEN L2AB1=((N-K+1)*AB1)/TAN(VWFAR)
565 IF HA>HM THEN BTAH2=(HM-Y)/LB
566 IF (HA<=HM) AND (HA>Y) THEN BTAH2=(HA-Y)/LB
567 IF (HA<=Y) AND (HA>=(D/2)) THEN BTAH2=(Y-HA)/LB
568 BTHR2=ATN(BTAH2/SQR(1-BTAH2*BTAH2))
575 SL2A=(LB*COS(BTHR1)-E)*SIN(SL1R)
580 SL2B=(LB*COS(BTHR2)-E)
585 SL2=(SL2A-L2AB1)/SL2B
590 SL2R=ATN(SL2/SQR(1-SL2*SL2))
600 SL3R=(SL1R+SL2R)/2
602 IF ABS(SL3R-SLRT)<9.999999E-06 THEN L1AB=-1
604 IF ABS(SL3R-SLRT)<9.999999E-06 GOTO 702
610 YA=(LB*COS(BTHR1)-E)*SIN(SLRT)-(LB*COS(BTHR2)-E)*SIN(SL3R)
620 L2AB2=YA/COS(SL3R)
640 IF ABS(L2AB2-L2AB1)<=.001 GOTO 700
650 IF L2AB2>L2AB1 THEN SL2R=SL3R
660 IF L2AB2<L2AB1 THEN SL1R=SL3R
670 GOTO 600
700 L1AB=(LB*COS(BTHR1)-E)*SIN(SLRT)-(LB*COS(BTHR2)-E)*SIN(SL3R)
702 IF L1AB<0 THEN L1AB=0 ELSE GOTO 710
703 SLR=((LB*COS(BTHR1)-E)*SIN(SLRT))/(LB*COS(BTHR2)-E)
704 IF SLR>1 THEN L1AB=(LB*COS(BTHR1)-E)*SIN(SLRT)-(LB*COS(BTHR2)-E)*SIN(SLRT)
705 IF SLR>1 THEN SL3R=SLRT
706 IF SLR>1 GOTO 710
708 SL3R=ATN(SLR/SQR(1-SLR*SLR))
710 L1=L1+L1AB:K=K+1:BTHR1=BTHR2:SL1R=SL3R:SLRT=SL3R
730 IF K<=N GOTO 560
740 IF (K-N)<1! GOTO 560
760 SSAI=ATN(H/L1):IF H>HT THEN SSAI=ATN(HT/L1)
765 SSAJ=SSAI*180/PI:SSAJ=90-SSAJ:SSAJ=SSAJ*PI/180
770 H1=(D/2)*SIN(SSAJ):R1=(D/2)*COS(SSAJ)
775 H2=(D/2)-AB-H1:R2=R1-H2/TAN(SSAI)
780 IF H<(HS+H2) GOTO 900
```

```
790 RD=(((D/2)^2)-((HM-H)^2))^.5
800 SSAI=ATN(H/(L1+RD-R2))
900 SSA(3,J)=SSAI*180/PI
1035 SSA(1,J)=H
1036 GOTO 1040
1037 IF (J-1)=0 THEN G=1 ELSE G=J-1
1038 SSA(2,J)=SSA(2,G):SSA(3,J)=SSA(3,G)
1039 SSA(1,J)=H
1040 LPRINT USING "###.##   ";SSA(1,J),SSA(2,J),SSA(3,J)
1045 GOTO 1060
1050 LPRINT USING "###.##   ";SSA(1,J),SSA(2,J),SSA(3,J)
1060 H=H+.5
1065 J=J+1
1066 L1=0!
1070 GOTO 350
1095 LPRINT " "
1100 LPRINT "TERRACE CUT IS USED ABOVE A BENCH HEIGHT OF ";HT
1102 INPUT "DO YOU WANT TO PLOT THE DATA, (Y/N)";ZZZZ$
1104 IF ZZZZ$="Y" THEN GOSUB 5000
1110 INPUT "DO YOU WANT TO CHANGE THE MAXIMUM SLEW ANGLE ON THE SLOPE SIDE, (Y/N)";Z$
1120 IF Z$="Y" GOTO 220
1150 INPUT "DO YOU WANT TO CHANGE THE VERTICAL WHEEL FREE ANGLE, (Y/N)";ZZZ$
1160 IF ZZZ$="Y" GOTO 120
1164 GOTO 1170
1165 PRINT "MAXIMUM SLEW ANGLE IS LESS THAN THE MINIMUM SLEW ANGLE"
1166 GOTO 1110
1170 END
5000 OPEN "COM2:2400,E,7,2,CS60000,DS60000" AS #1
5005 ON ERROR GOTO 5900
5010 HMAX1=INT(HMAX+.5):HMIN1=INT(HMIN-.5)
5015 IF HMIN1<=0 THEN HMIN1=0
5020 YFACT=(1300/(HMAX1-HMIN1)):XFACT=80/9
5030 PRINT #1,";: A H "'INITIALIZE PLOTTER
5040 PRINT #1,"U 0,0 D 0,0 0,2200 1700,2200 1700,0 0,0 "
5050 PRINT #1,"U 300,200 D 300,200 300,2000 1500,2000 1500,200 300,200 "
5060 PRINT #1, "U 400,1940 S11+ RANGE OF SIDE SLOPE ANGLES AS A FUNCTION OF HEIGHT _ "
5065 PRINT #1, "U 560,1905 S11+ FOR THE DROPPING CUT (MODEL C) _ "
5070 PRINT #1, "U 750,1845 S12 " NAME1$ " _ "
5072 MXSL$=STR$(MXSL):VWFA$=STR$(VWFA)
5076 PRINT #1, "U 350,1800 S11 MAX SLEW ANGLE SLOPE SIDE " MXSL$ " _ "
5078 PRINT #1, "U 850,1800 S11 VERTICAL WHEEL FREE ANGLE " VWFA$ " _ "
5080 FOR K=0 TO 90 STEP 10
5090 X$=STR$(INT(K*XFACT+500.5)):YY$="460":HMIN$="450"
5100 IF K=0 THEN PRINT #1," U "X$","HMIN$
5110 PRINT #1, " D "X$","HMIN$
5120 PRINT #1, " D "X$","YY$
5130 PRINT #1, " D "X$","HMIN$
5140 NEXT K
5150 FOR K=0 TO 90 STEP 10
5160 X$=STR$(INT(K*XFACT+460.5)):XX$=STR$(K):Y$="420.5"
5170 PRINT #1," U "X$","Y$" S11+ "XX$" _ "
5180 NEXT K
5190 PRINT #1, " U 500,450 "
5200 FOR K=HMIN1 TO HMAX1 STEP 1
```

```
5210 X$="500":X1$="510":Y$=STR$(INT((K-HMIN1)*YFACT+450.5))
5220 PRINT #1, " D "X$","Y$
5230 PRINT #1, " D "X1$","Y$
5240 PRINT #1, " D "X$","Y$
5250 NEXT K
5260 FOR K=HMIN1 TO HMAX1 STEP 1
5270 X$="415":Y$=STR$(INT((K-HMIN1)*YFACT+450.5)):YY$=STR$(K)
5280 PRINT #1,"U "X$","Y$
5290 PRINT #1," S11+ "YY$" _"
5300 NEXT K
5310 PRINT #1,"U 800,380":PRINT #1," S11+ SIDE SLOPE ANGLE _ "
5320 PRINT #1,"U 350,900":PRINT #1," S41+ BENCH HEIGHT (M) _ "
5330 PRINT #1," EL "
5340 FOR I=2 TO 3
5410 FOR J=1 TO ICOUNT
5420 X$=STR$(INT(SSA(I,J)*XFACT+500.5)):Y$=STR$(INT((SSA(1,J)-HMIN1)*YFACT+450.5))
5430 IF J=1 THEN PRINT #1,"U "X$,Y$" "
5431 IF J-1=0 THEN G=1 ELSE G=J-1
5432 IF SSA(I,J)=0! THEN PRINT #1, "U "X$,Y$" "
5434 IF SSA(I,J)=0! GOTO 5450
5436 IF SSA(I,G)=0! AND SSA(I,J)<>0! THEN PRINT #1, "U "X$,Y$" "
5440 PRINT #1,"D " X$","Y$" "
5450 NEXT J:NEXT I
5455 PRINT #1," EL "
5456 PRINT #1, "U 350,280 S11+ NOTE: A SIDE SLOPE ANGLE OF 90 DEGREES CAN ALWAYS BE FORMED _ "
5560 PRINT #1," H ":CLOSE
5570 RETURN
5900 FOR IJKL=0 TO 1000:NEXT IJKL:RESUME
```

APPENDIX I-6

```
LOAD"B:DRCUTW.BAS
Ok
RUN
NAME OF BWE? O&K SH 630
DIGGING WHEEL DIAMETER TO OUTSIDE OF BUCKETS? 8.4
DIGGING WHEEL DIAMETER WITHOUT BUCKETS? 6.9
LENGTH OF BWE LOAD BOOM? 14.35
MAXIMUM LIFT OF WHEEL BOOM? 13.3
THE DISTANCE 'E'? -1.1
ELEVATION OF LOAD BOOM PIVOT POINT? 8.15
MINIMUM BENCH HEIGHT? 4
SAFETY DISTANCE REQUIRED BETWEEN SLOPE TOES AND CRAWLER? 1
DISTANCE BETWEEN CENTRE LINE OF ADVANCE AND EDGE OF CRAWLER, IE. CW? 4.95
MAXIMUM SLEW ANGLE ON PIT SIDE AT GROUND LEVEL? 30
MAXIMUM SLEW ANGLE OF TOP TERRACE ON SIDE SLOPE SIDE? 70
DO YOU WANT TO PLOT THE DATA, (Y/N)? N
DO YOU WANT TO CHANGE MAXIMUM SLEW ANGLES, (Y/N)? Y
MAXIMUM SLEW ANGLE ON PIT SIDE AT GROUND LEVEL? 30
MAXIMUM SLEW ANGLE OF TOP TERRACE ON SIDE SLOPE SIDE? 90
DO YOU WANT TO PLOT THE DATA, (Y/N)? N
DO YOU WANT TO CHANGE MAXIMUM SLEW ANGLES, (Y/N)? N
Ok

1LIST   2RUN   3LOAD"   4SAVE"   5CONT 6,"LPT1 7TRON 8TROFF9KEY    0SCREEN
```

```
10 DIM W(8,40)
20 PI=3.141593
30 INPUT "NAME OF BWE";NAME1$
40 INPUT "DIGGING WHEEL DIAMETER TO OUTSIDE OF BUCKETS";D
45 INPUT "DIGGING WHEEL DIAMETER WITHOUT BUCKETS";D1
50 INPUT "LENGTH OF BWE LOAD BOOM";LB
60 INPUT "MAXIMUM LIFT OF WHEEL BOOM";HM
70 INPUT "THE DISTANCE 'E'";E
80 INPUT "ELEVATION OF LOAD BOOM PIVOT POINT";Y
90 INPUT "MINIMUM BENCH HEIGHT";HMIN
100 INPUT "SAFETY DISTANCE REQUIRED BETWEEN SLOPE TOES AND CRAWLER";F
110 INPUT "DISTANCE BETWEEN CENTRE LINE OF ADVANCE AND EDGE OF CRAWLER, IE. CW";CW
120 I%=1
130 AB=(D-D1)/2
160 INPUT "MAXIMUM SLEW ANGLE ON PIT SIDE AT GROUND LEVEL";PSSA
170 INPUT "MAXIMUM SLEW ANGLE OF TOP TERRACE ON SIDE SLOPE SIDE";SSSA
180 BTAD=(Y-(.5*D))/LB
190 BTDR=ATN(BTAD/SQR(1-BTAD*BTAD))
200 MNSL=(CW+F)/((LB-E)*COS(BTDR))
210 MNSLR=ATN(MNSL/SQR(1-MNSL*MNSL))
220 PSSAR=PSSA*PI/180
230 SSSAR=SSSA*PI/180
240 IF SSSAR(MNSLR GOTO 1270
250 BTAH=(HM-Y)/LB
260 BTHR=ATN(BTAH/SQR(1-BTAH*BTAH))
275 AA=(LB*COS(BTHR)-E)*SIN(SSSAR)
280 BBB=(LB*COS(BTDR)-E)*SIN(MNSLR)
290 L1A=AA-BBB
300 LPRINT " "
310 LPRINT "MAXIMUM WIDTH OF CUT AS A FUNCTION OF HEIGHT AND SIDE SLOPE ANGLE FOR THE ";NAME1$
320 LPRINT " "
330 LPRINT "NOTE: MAXIMUM SLEW ANGLE ON SIDE SLOPE SIDE IS";SSSA
340 LPRINT "NOTE: MAXIMUM SLEW ANGLE ON PIT SIDE IS";PSSA
350 LPRINT "NOTE: FOR DROPPING CUT
360 LPRINT "NOTE: 'W' IS THE CUT WIDTH @ THE SIDE SLOPE ANGLE"
370 LPRINT "HEIGHT     W@30     W@40     W@50     W@60     W@70     W@80     W@89"
390 HHMAX%=(HM+(.2*D))/.5
400 HMAX=HHMAX%*.5
405 ICOUNT=(HMAX-HMIN)*2+1
406 HHT%=(HM-(D/2))/.1
407 HT=HHT%*.1
408 HS=HT+AB
410 H=HMIN
415 J%=1:J=1
420 I=2
430 W(I,J)=99!
440 I=I+1
450 IF I(9 GOTO 430
460 IF H)HMAX GOTO 1151
470 I=2
480 SS=30
485 SSI=90-SS
490 SSR=SS*PI/180
491 SSIR=SSI*PI/180
```

```
494 IF H)HM  GOTO 1065
500 L1=H/TAN(SSR)
510 IF L1)L1A GOTO 1060
512 R1=(D/2)*COS(SSIR)
514 H2=(D/2)-AB-(D/2)*SIN(SSIR)
516 R3=H2/TAN(SSR)
520 H1=H+(D/2)
530 IF H1)HM THEN BTAH=(HM-Y)/LB
540 IF (H1(=HM) AND (H1)Y) THEN BTAH=(H1-Y)/LB
550 IF (H1(=Y) AND (H1)=(D/2)) THEN BTAH=(Y-H1)/LB
590 BTHR=ATN(BTAH/SQR(1-BTAH*BTAH))
600 IF H(=HS THEN RD=R1-R3
610 IF H)HS AND H(=(HS+H2) THEN RD=R1-((H2-(H-HS))/TAN(SSR))
620 IF H)=(HS+H2) AND H(=HM THEN RD=(((D/2)^2)-((HM-H)^2))^.5
1010 A=(LB*COS(BTHR)-E+RD)*SIN(SSSAR)
1020 B=(LB*COS(BTDR)-E)*SIN(PSSAR)
1030 WI=A+B-L1
1040 IF WI(0! GOTO 1060 ELSE GOTO 1061
1060 WI=0!
1061 W(I,J)=WI
1063 GOTO 1080
1065 IF (J-1)=0 THEN G=1 ELSE G=J-1
1070 W(I,J)=W(I,G)
1080 I=I+1
1090 SS=SS+10
1100 IF SS=90 THEN SS=89
1110 IF SS(90 GOTO 485
1115 W(1,J)=H
1120 LPRINT USING "###.##    ";W(1,J),W(2,J),W(3,J),W(4,J),W(5,J),W(6,J),W(7,J),W(8,J)
1125 J=J+1
1130 H=H+.5
1133 GOTO 460
1151 Q=8
1153 YMAX=W(Q,1)
1155 IF YMAX=0 THEN Q=Q-1 ELSE GOTO 1180
1157 GOTO 1153
1180 LPRINT " "
1190 LPRINT "TERRACE CUT IS USED ABOVE BENCH HEIGHT OF ";HT
1192 INPUT "DO YOU WANT TO PLOT THE DATA, (Y/N)";ZZZZ$
1194 IF ZZZZ$="Y" THEN GOSUB 5000
1200 INPUT "DO YOU WANT TO CHANGE MAXIMUM SLEW ANGLES, (Y/N)";Z$
1210 IF Z$="Y" GOTO 160
1260 GOTO 1290
1270 PRINT "SLEW ANGLE IS LESS THAN THE MINIMUM ANGLE"
1280 GOTO 1200
1290 END
5000 OPEN "COM2:2400,E,7,2,CS60000,DS60000" AS #1
5005 ON ERROR GOTO 6000
5010 HMAX1=INT(HMAX+.5):HMIN1=INT(HMIN-.5)
5012 YY=CINT(YMAX+.5):YYY=INT(BBB+B)
5017 IF YY/2 )( INT(YY/2) THEN YY=YY+1
5018 IF YYY/2 )( INT(YYY/2) THEN YYY=YYY-1
5020 YFACT=(1300/(HMAX1-HMIN1)):XFACT=800/(YY-YYY)
5040 PRINT #1,";: A H " 'INITIALIZE PLOTTER
```

```
5050 PRINT #1,"U 0,0 D 0,0 0,2200 1700,2200 1700,0 0,0 "
5055 PRINT #1,"U 300,200 D 300,200 300,2000 1500,2000 1500,200 300,200 "
5060 PRINT #1, "U 500,1960 S11+ WIDTH OF CUT AS A FUNCTION OF BENCH HEIGHT _ "
5065 PRINT #1, "U 680,1925 S11+ FOR THE DROPPING CUT _ "
5070 PRINT #1, "U 750,1875 S12 " NAME1$ " _ "
5072 MXSL$=STR$(SSSA):PSSA$=STR$(PSSA)
5077 PRINT #1, "U 500,1815 S11 MAX SLEW ANGLE SLOPE SIDE " MXSL$ " _ "
5078 PRINT #1, "U 950,1815 S11 MAX SLEW ANGLE PIT SIDE " PSSA$ " _ "
5080 FOR K=0 TO (YY-YYY) STEP 2
5100 X$=STR$(INT(K*XFACT+500.5)):YY$="460":HMIN$="450"
5110 IF K=0 THEN PRINT #1," U "X$","HMIN$
5120 PRINT #1, " D "X$","HMIN$
5140 PRINT #1, " D "X$","YY$
5160 PRINT #1, " D "X$","HMIN$
5170 NEXT K
5180 FOR K=0 TO (YY-YYY) STEP 2
5185 X$=STR$(INT(K*XFACT+460.5)):XX$=STR$(K+YYY):Y$="420.5"
5190 PRINT #1," U "X$","Y$" S11+ "XX$" _ "
5195 NEXT K
5200 PRINT #1, " U 500,450 "
5220 FOR K=HMIN1 TO HMAX1 STEP 1
5240 X$="500":X1$="510":Y$=STR$(INT((K-HMIN1)*YFACT+450.5))
5260 PRINT #1, " D "X$","Y$
5280 PRINT #1, " D "X1$","Y$
5300 PRINT #1, " D "X$","Y$
5320 NEXT K
5330 FOR K=HMIN1 TO<HMAX1 STEP 1
5332 X$="415":Y$=STR$(INT((K-HMIN1)*YFACT+450.5)):YY$=STR$(K)
5334 PRINT #1,"U "X$","Y$
5336 PRINT #1," S11+ "YY$" _"
5338 NEXT K
5340 PRINT #1,"U 800,380":PRINT #1," S11+ WIDTH OF CUT (M) _ "
5350 PRINT #1,"U 350,900":PRINT #1," S41+ SLOPE HEIGHT (M) _ "
5355 PRINT #1," EL "
5360 FOR I=2 TO 8
5365 IF I=2 THEN PRINT #1,"L0 "
5366 IF I=3 THEN PRINT #1,"L2 "
5367 IF I=4 THEN PRINT #1,"L4 "
5368 IF I=5 THEN PRINT #1,"L6 "
5369 IF I=6 THEN PRINT #1,"L8 "
5370 IF I=7 THEN PRINT #1,"L9 "
5375 IF I=8 THEN PRINT #1,"L: "
5380 FOR J=1 TO ICOUNT
5400 X$=STR$(INT(W(I,J)*XFACT+500.5-(XFACT*YYY)))
5410 Y$=STR$(INT((W(1,J)-HMIN1)*YFACT+450.5))
5415 IF J-1=0 THEN G=1 ELSE G=J-1
5420 IF J=1 THEN PRINT #1,"U "X$,Y$" "
5423 IF W(I,J)=0! THEN PRINT #1, "U "X$,Y$" "
5426 IF W(I,J)=0! GOTO 5460
5440 IF W(I,G)=0 THEN PRINT #1,"U " X$","Y$" " ELSE PRINT #1,"D " X$","Y$" "
5460 NEXT J:NEXT I
5461 PRINT #1,"L0 U 550,320 D 650,320 "
5462 PRINT #1,"L2 U 800,320 D 900,320 "
5463 PRINT #1,"L4 U 1050,320 D 1150,320 "
```

```
5464 PRINT #1,"L6 U 550,290 D 650,290 "
5465 PRINT #1,"L8 U 800,290 D 900,290 "
5466 PRINT #1,"L9 U 1050,290 D 1150,290 "
5470 PRINT #1,"L: U 550,260 D 650,260 "
5475 PRINT #1,"EL "
5476 PRINT #1,"L0 "
5480 PRINT #1," U 400,290 S11+ LEGEND _"
5488 PRINT #1," U 670,320 S11 SSA=30 _ "
5489 PRINT #1," U 920,320 S11 SSA=40 _ "
5490 PRINT #1," U 1170,320 S11 SSA=50 _ "
5491 PRINT #1," U 670,290 S11 SSA=60 _ "
5492 PRINT #1," U 920,290 S11 SSA=70 _ "
5493 PRINT #1," U 1170,290 S11 SSA=80 _ "
5494 PRINT #1," U 670,260 S11 SSA=89 _ "
5497 PRINT #1, "U 550,230 S11 SSA=SIDE SLOPE ANGLE _ "
5499 PRINT #1," H ":CLOSE
5500 RETURN
6000 FOR IJKL=0 TO 1000:NEXT IJKL:RESUME
```

APPENDIX II

APPENDIX II-1

MINIMUM OVERALL FRONT SLOPE AS A FUNCTION OF HEIGHT AND ADVANCE OF TERRACE FOR THE O&K SH 630

'A' IS ADVANCE AND CALCULATED NUMBERS ARE FRONT SLOPE ANGLE
NOTE: FOR TERRACE CUT

HEIGHT	A=1	A=2	A=3	A=4	A=5	A=6	A=7	A=8
4.50	2.30	2.65	3.13	3.83	4.93	6.90	11.47	32.06
5.00	6.01	6.91	8.13	9.86	12.53	17.10	26.55	53.09
5.50	9.58	10.97	12.84	15.45	19.34	25.68	37.34	61.56
6.00	13.01	14.85	17.27	20.60	25.41	32.84	45.18	66.33
6.50	16.32	18.55	21.44	25.35	30.82	38.85	51.10	69.59
7.00	19.51	22.07	25.37	29.72	35.64	43.95	55.77	72.09
7.50	22.58	25.44	29.07	33.76	39.98	48.34	59.60	74.16
8.00	25.55	28.67	32.56	37.51	43.89	52.18	62.83	75.96
8.50	28.42	31.76	35.87	41.00	47.45	55.58	65.64	77.58
9.00	31.20	34.72	39.01	44.26	50.72	58.64	68.14	79.08
9.50	33.90	37.58	42.00	47.32	53.74	61.42	70.40	80.50
10.00	36.52	40.33	44.85	50.21	56.55	63.98	72.48	81.84
10.50	39.08	42.99	47.58	52.94	59.19	66.36	74.42	83.15
11.00	41.58	45.57	50.20	55.55	61.68	68.60	76.24	84.41
11.50	44.02	48.08	52.73	58.04	64.04	70.71	77.98	85.66
12.00	46.41	50.52	55.18	60.43	66.29	72.73	79.65	86.88
12.50	48.76	52.91	57.56	62.74	68.46	74.67	81.26	88.10
13.00	51.08	55.24	59.87	64.98	70.56	76.54	82.83	89.31
13.50	53.05	57.19	61.76	66.75	72.15	77.89	83.89	90.00
14.00	54.48	58.54	62.99	67.82	73.01	78.49	84.20	90.00
14.50	55.82	59.80	64.13	68.80	73.79	79.04	84.48	90.00
15.00	57.07	60.97	65.18	69.70	74.50	79.53	84.74	90.00

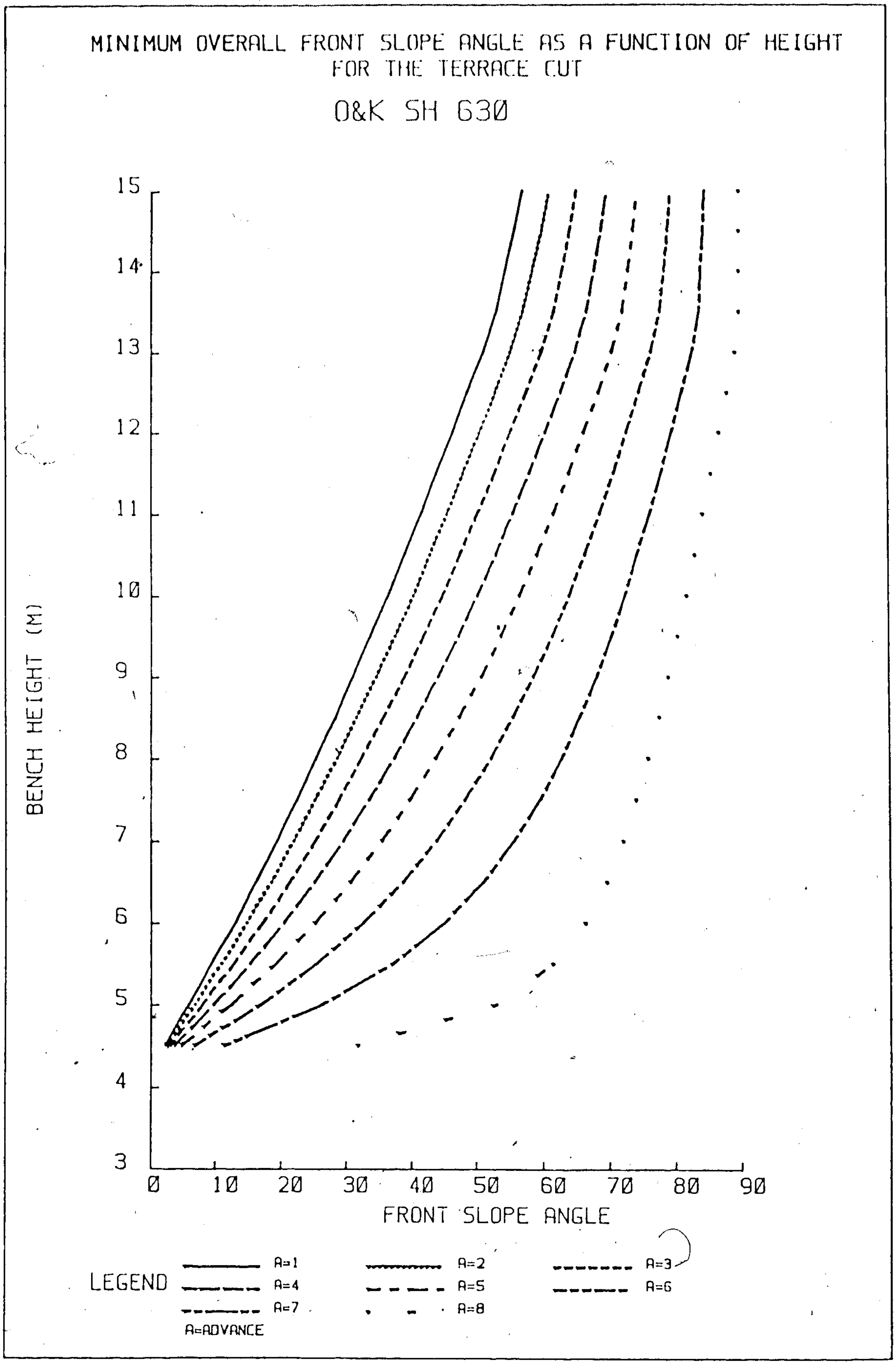
FOR HEIGHT LESS THAN 4.5 THERE IS NO LIMIT ON THE ADVANCE

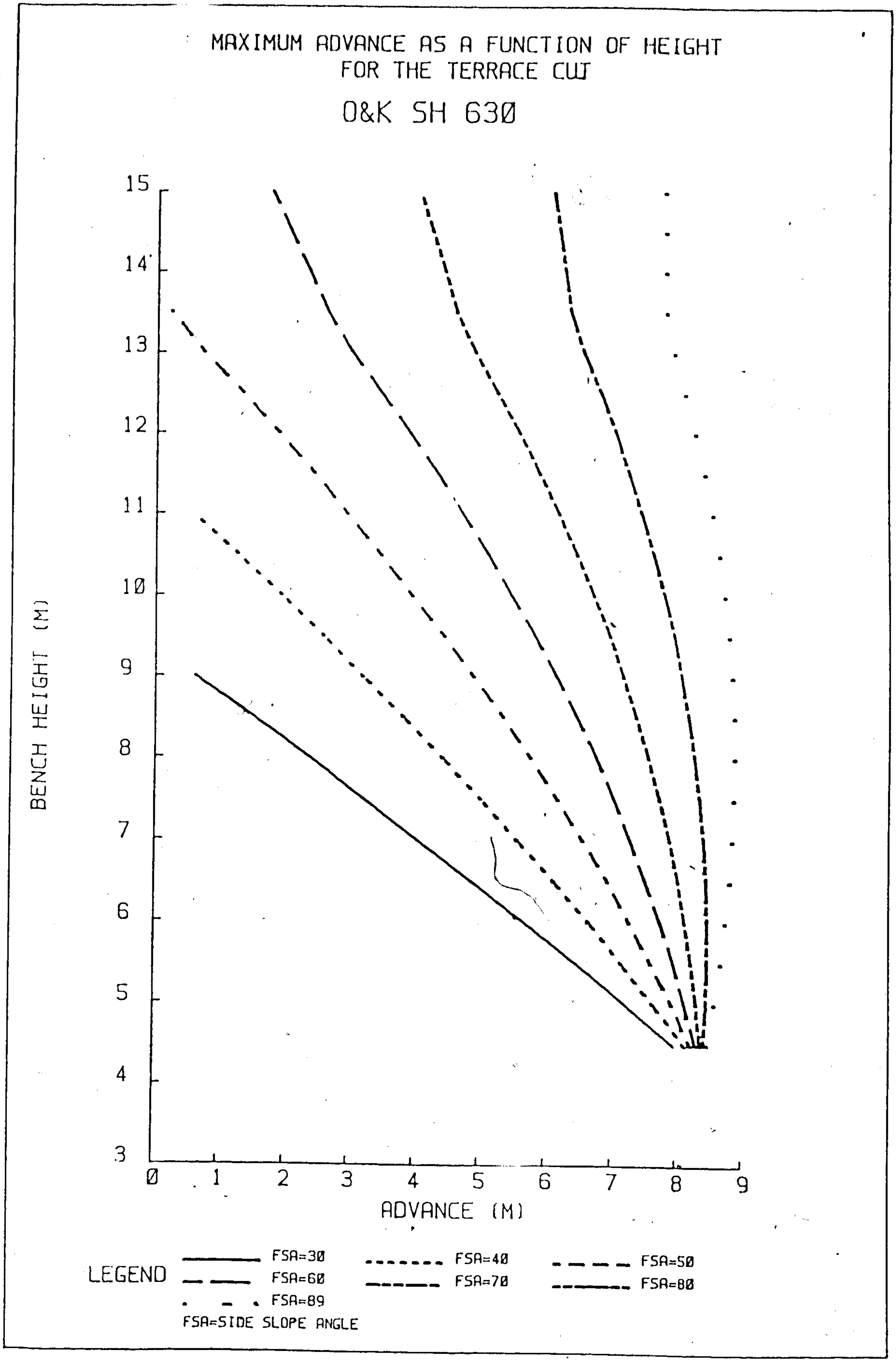
MAXIMUM ADVANCE AS A FUNCTION OF HEIGHT AND FRONT SLOPE ANGLE FOR THE O&K SH 630

'A' IS ADVANCE @ FRONT SLOPE ANGLE
NOTE: FOR TERRACE CUT

HEIGHT	A@30	A@40	A@50	A@60	A@70	A@80	A@89
4.50	7.96	8.12	8.23	8.31	8.37	8.43	8.47
5.00	7.22	7.65	7.93	8.14	8.31	8.46	8.59
5.50	6.45	7.15	7.61	7.95	8.23	8.47	8.68
6.00	5.67	6.64	7.28	7.75	8.13	8.47	8.76
6.50	4.87	6.11	6.93	7.53	8.02	8.45	8.82
7.00	4.06	5.57	6.56	7.29	7.89	8.41	8.86
7.50	3.22	5.00	6.17	7.03	7.74	8.35	8.88
8.00	2.37	4.42	5.76	6.76	7.57	8.28	8.88
8.50	1.50	3.82	5.34	6.46	7.38	8.19	8.87
9.00	0.61	3.21	4.90	6.15	7.18	8.08	8.84
9.50	0.00	2.57	4.44	5.83	6.96	7.95	8.79
10.00	0.00	1.92	3.96	5.48	6.72	7.81	8.73
10.50	0.00	1.25	3.47	5.12	6.46	7.65	8.65
11.00	0.00	0.56	2.96	4.74	6.19	7.47	8.55
11.50	0.00	0.00	2.43	4.34	5.90	7.27	8.43
12.00	0.00	0.00	1.88	3.92	5.59	7.05	8.29
12.50	0.00	0.00	1.31	3.48	5.25	6.81	8.13
13.00	0.00	0.00	0.72	3.03	4.90	6.55	7.95
13.50	0.00	0.00	0.19	2.63	4.61	6.36	7.83
14.00	0.00	0.00	0.00	2.34	4.43	6.27	7.82
14.50	0.00	0.00	0.00	2.05	4.25	6.18	7.82
15.00	0.00	0.00	0.00	1.76	4.06	6.09	7.81

FOR HEIGHT LESS THEN 4.5 THERE IS NO LIMIT TO ADVANCE


MINIMUM OVERALL FRONT SLOPE ANGLE AS A FUNCTION OF HEIGHT
FOR THE TERRACE CUT
O&K SH 630
BENCH HEIGHT (M)
FRONT SLOPE ANGLE
LEGEND
A=1
A=2
A=3
A=4
A=5
A=6
A=7
A=8
A=ADVANCE

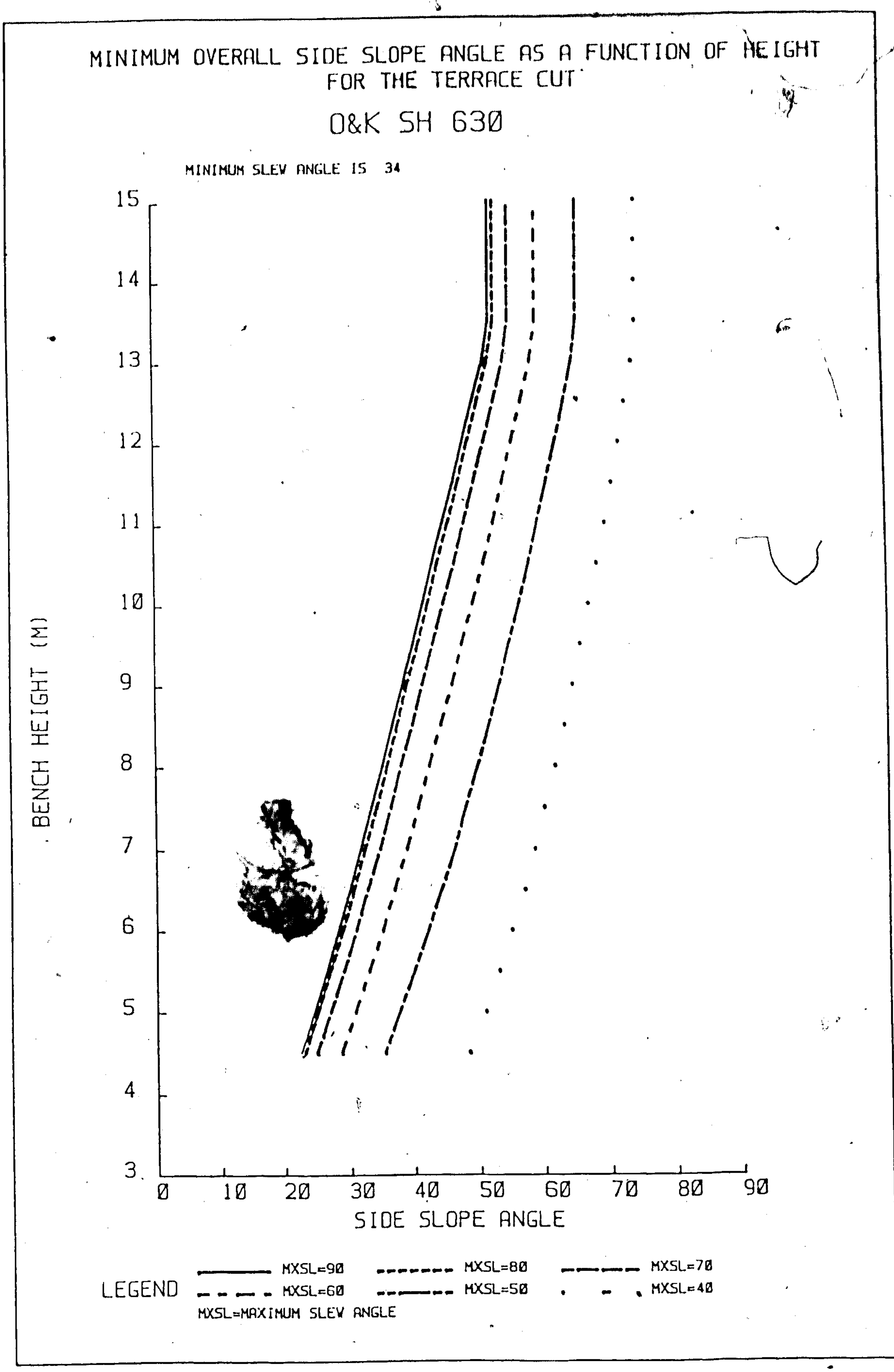

MAXIMUM ADVANCE AS A FUNCTION OF HEIGHT
FOR THE TERRACE CUT
O&K SH 630
BENCH HEIGHT (M)
ADVANCE (M)
15
14
13
12
11
10
9
8
7
6
5
4
3
0
1
2
3
4
5
6
7
8
9
LEGEND
FSA=30
FSA=40
FSA=50
FSA=60
FSA=70
FSA=80
FSA=89
FSA=SIDE SLOPE ANGLE

APPENDIX II-2

MINIMUM OVERALL SIDE SLOPE ANGLE AS A FUNCTION OF HEIGHT FOR THE O&K SH 630

NOTE: MINIMUM SLEW ANGLE IS 34
SL IS THE MAXIMUM SLEW ANGLE ON THE SLOPE SIDE
NOTE: FOR TERRACE CUT

HEIGHT	SL=90	SL=80	SL=70	SL=60	SL=50	SL=40
4.50	22.53	23.09	24.91	28.53	35.27	48.38
5.00	24.50	25.09	27.02	30.81	37.76	50.81
5.50	26.41	27.03	29.05	32.98	40.09	53.01
6.00	28.27	28.91	31.01	35.07	42.28	55.03
6.50	30.07	30.74	32.90	37.07	44.35	56.88
7.00	31.84	32.53	34.75	38.99	46.31	58.61
7.50	33.56	34.27	36.54	40.84	48.17	60.22
8.00	35.25	35.98	38.29	42.64	49.96	61.74
8.50	36.91	37.65	40.00	44.39	51.67	63.17
9.00	38.55	39.30	41.67	46.08	53.32	64.54
9.50	40.16	40.92	43.32	47.74	54.91	65.85
10.00	41.76	42.52	44.93	49.36	56.45	67.10
10.50	43.34	44.11	46.53	50.94	57.95	68.31
11.00	44.91	45.68	48.11	52.50	59.40	69.48
11.50	46.47	47.25	49.67	54.04	60.83	70.62
12.00	48.03	48.80	51.22	55.55	62.22	71.72
12.50	49.58	50.36	52.76	57.05	63.60	72.81
13.00	51.14	51.91	54.30	58.53	64.95	73.87
13.50	52.07	52.84	55.22	59.42	65.75	74.51
14.00	52.07	52.84	55.22	59.42	65.75	74.51
14.50	52.07	52.84	55.22	59.42	65.75	74.51
15.00	52.07	52.84	55.22	59.42	65.75	74.51


MINIMUM OVERALL SIDE SLOPE ANGLE AS A FUNCTION OF HEIGHT
FOR THE TERRACE CUT
O&K SH 630
MINIMUM SLEV ANGLE IS 34
BENCH HEIGHT (M)
15
14
13
12
11
10
9
8
7
6
5
4
3
0
10
20
30
40
50
60
70
80
90
SIDE SLOPE ANGLE
LEGEND
MXSL=90
MXSL=80
MXSL=70
MXSL=60
MXSL=50
MXSL=40
MXSL=MAXIMUM SLEV ANGLE

APPENDIX II-3

WIDTH OF CUT AS A FUNCTION OF HEIGHT AND SIDE SLOPE ANGLE FOR THE O&K SH 630

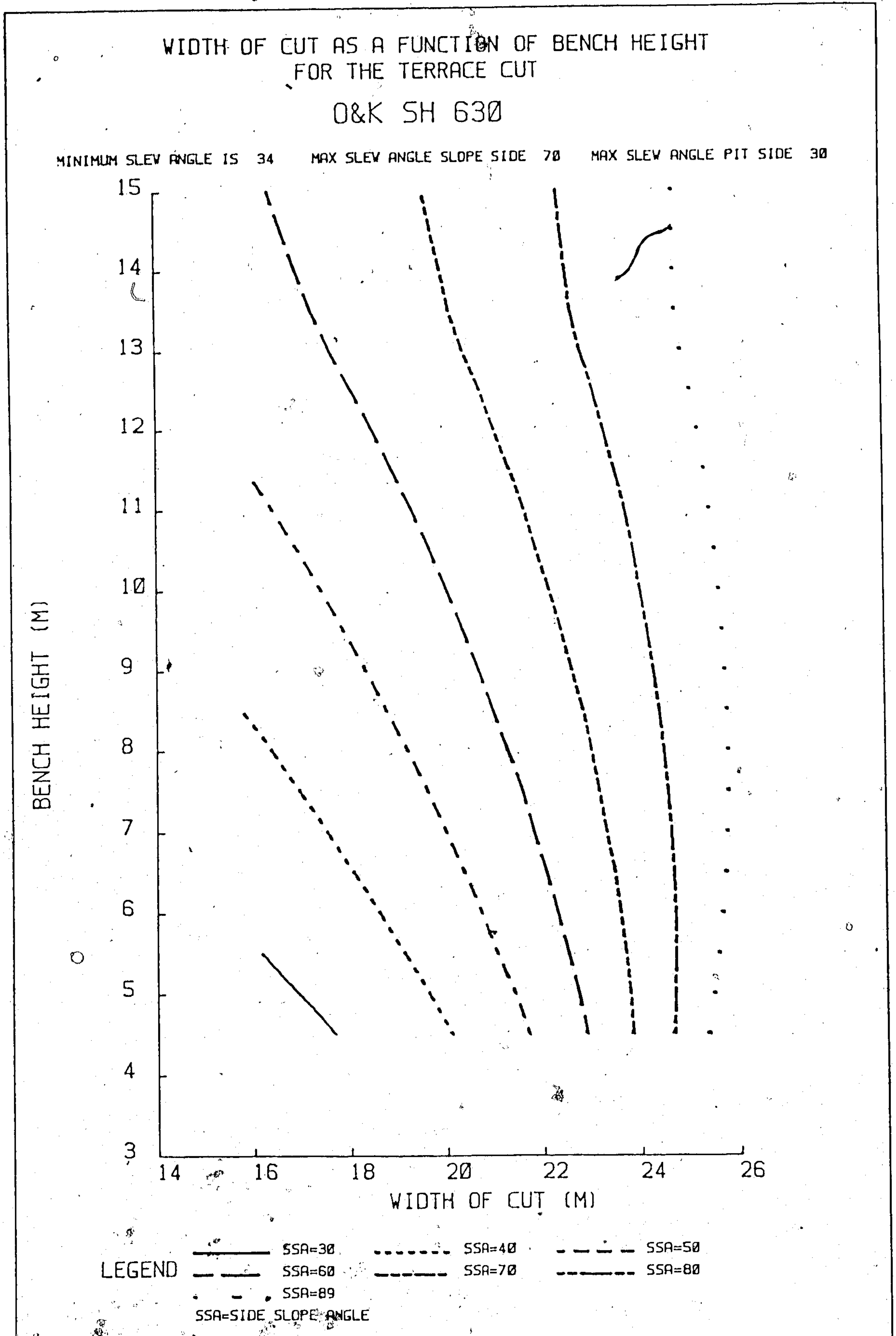
NOTE: MAXIMUM SLEW ANGLE FOR THE TOP TERRACE ON SIDE SLOPE SIDE IS 70
NOTE: MAXIMUM SLEW ANGLE ON THE OPEN SIDE IS 30
'W' IS THE CUT WIDTH @ THE SIDE SLOPE ANGLE FOR THE TERRACE CUT
MINIMUM SLEW ANGLE IS 34

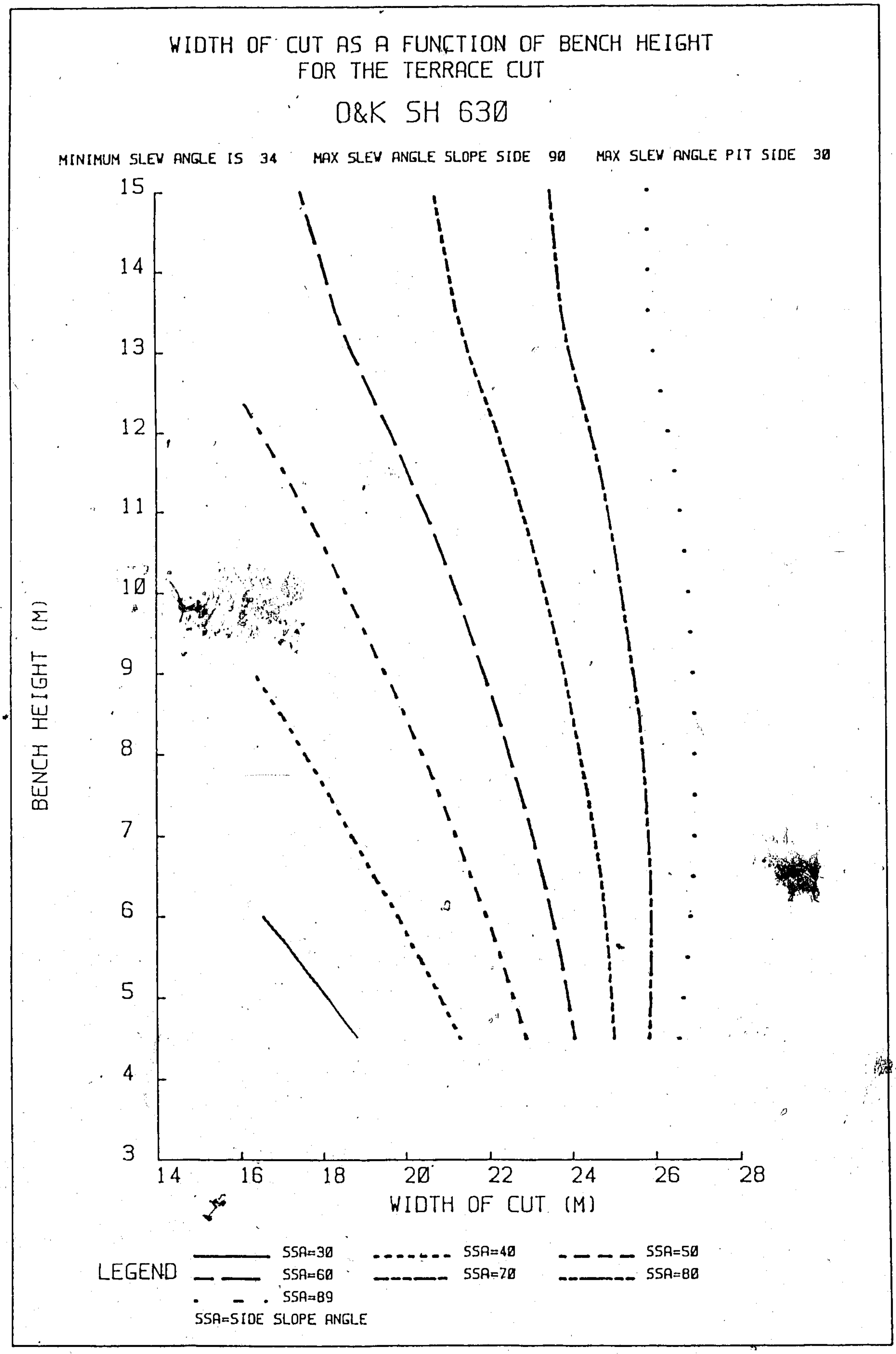
TERRACE CUT HEIGHT	W@30	W@40	W@50	W@60	W@70	W@80	W@89
4.50	17.68	20.11	21.69	22.87	23.83	24.68	25.39
5.00	16.92	19.63	21.39	22.70	23.76	24.70	25.50
5.50	16.15	19.13	21.07	22.51	23.68	24.71	25.58
6.00	0.00	18.61	20.73	22.30	23.58	24.70	25.66
6.50	0.00	18.08	20.37	22.07	23.46	24.68	25.71
7.00	0.00	17.53	20.00	21.83	23.32	24.64	25.75
7.50	0.00	16.96	19.61	21.57	23.17	24.58	25.77
8.00	0.00	16.38	19.20	21.29	23.00	24.50	25.77
8.50	0.00	15.78	18.78	21.00	22.82	24.41	25.76
9.00	0.00	0.00	18.34	20.69	22.61	24.30	25.73
9.50	0.00	0.00	17.88	20.37	22.40	24.18	25.69
10.00	0.00	0.00	17.41	20.03	22.16	24.04	25.63
10.50	0.00	0.00	16.92	19.67	21.91	23.88	25.55
11.00	0.00	0.00	16.41	19.29	21.64	23.70	25.45
11.50	0.00	0.00	15.89	18.90	21.35	23.51	25.34
12.00	0.00	0.00	0.00	18.49	21.05	23.30	25.21
12.50	0.00	0.00	0.00	18.06	20.73	23.07	25.06
13.00	0.00	0.00	0.00	17.61	20.39	22.83	24.89
13.50	0.00	0.00	0.00	17.22	20.10	22.63	24.78
14.00	0.00	0.00	0.00	16.93	19.92	22.55	24.77
14.50	0.00	0.00	0.00	16.64	19.74	22.46	24.76
15.00	0.00	0.00	0.00	16.35	19.55	22.37	24.75

WIDTH OF CUT AS A FUNCTION OF HEIGHT AND SIDE SLOPE ANGLE FOR THE O&K SH 630

NOTE: MAXIMUM SLEW ANGLE FOR THE TOP TERRACE ON SIDE SLOPE SIDE IS 80
NOTE: MAXIMUM SLEW ANGLE ON THE OPEN SIDE IS 30
'W' IS THE CUT WIDTH @ THE SIDE SLOPE ANGLE FOR THE TERRACE CUT
MINIMUM SLEW ANGLE IS 34
TERRACE CUT

HEIGHT	W@30	W@40	W@50	W@60	W@70	W@80	W@89
4.50	18.54	20.97	22.56	23.74	24.70	25.54	26.26
5.00	17.79	20.50	22.26	23.57	24.63	25.57	26.37
5.50	17.03	20.00	21.94	23.38	24.55	25.59	26.46
6.00	16.25	19.49	21.61	23.18	24.46	25.58	26.54
6.50	0.00	18.96	21.25	22.95	24.34	25.56	26.59
7.00	0.00	18.41	20.88	22.71	24.21	25.52	26.63
7.50	0.00	17.85	20.49	22.45	24.06	25.46	26.65
8.00	0.00	17.26	20.09	22.18	23.89	25.39	26.66
8.50	0.00	16.67	19.66	21.89	23.70	25.30	26.65
9.00	0.00	16.05	19.22	21.58	23.50	25.19	26.62
9.50	0.00	0.00	18.77	21.25	23.28	25.06	26.57
10.00	0.00	0.00	18.29	20.91	23.04	24.92	26.51
10.50	0.00	0.00	17.80	20.55	22.79	24.76	26.43
11.00	0.00	0.00	17.29	20.17	22.51	24.58	26.33
11.50	0.00	0.00	16.76	19.77	22.22	24.38	26.21
12.00	0.00	0.00	16.21	19.35	21.91	24.17	26.07
12.50	0.00	0.00	0.00	18.92	21.58	23.93	25.92
13.00	0.00	0.00	0.00	18.46	21.24	23.68	25.74
13.50	0.00	0.00	0.00	18.06	20.94	23.48	25.62
14.00	0.00	0.00	0.00	17.77	20.76	23.39	25.61
14.50	0.00	0.00	0.00	17.49	20.58	23.30	25.60
15.00	0.00	0.00	0.00	17.20	20.40	23.21	25.60


WIDTH OF CUT AS A FUNCTION OF BENCH HEIGHT
FOR THE TERRACE CUT
O&K SH 630
MINIMUM SLEV ANGLE IS 34
MAX SLEV ANGLE SLOPE SIDE 70
MAX SLEV ANGLE PIT SIDE 30
BENCH HEIGHT (M)
WIDTH OF CUT (M)
3
4
5
6
7
8
9
10
11
12
13
14
15
14
16
18
20
22
24
26
LEGEND
SSA=30
SSA=40
SSA=50
SSA=60
SSA=70
SSA=80
SSA=89
SSA=SIDE SLOPE ANGLE


WIDTH OF CUT AS A FUNCTION OF BENCH HEIGHT
FOR THE TERRACE CUT
O&K SH 630
MINIMUM SLEW ANGLE IS 34
MAX SLEW ANGLE SLOPE SIDE 90
MAX SLEW ANGLE PIT SIDE 30
BENCH HEIGHT (M)
15
14
13
12
11
10
9
8
7
6
5
4
3
14
16
18
20
22
24
26
28
WIDTH OF CUT (M)
LEGEND
SSA=30
SSA=40
SSA=50
SSA=60
SSA=70
SSA=80
SSA=89
SSA=SIDE SLOPE ANGLE

APPENDIX II-4

OVERALL MINIMUM FRONT SLOPE AS A FUNCTION OF HEIGHT AND ADVANCE FOR THE O&K SH 630

'A' IS ADVANCE AND CALCULATED NUMBERS ARE FRONT SLOPE ANGLE
NOTE: FOR DROPPING CUT

HEIGHT	A=1	A=2	A=3	A=4	A=5	A=6	A=7	A=8
4.00	26.70	29.91	33.90	38.92	45.34	53.56	63.97	76.59
4.50	29.53	32.95	37.13	42.31	48.77	56.82	66.65	78.17
5.00	32.28	35.87	40.21	45.49	51.94	59.76	69.04	79.63
5.50	34.95	38.68	43.14	48.48	54.87	62.45	71.23	81.02
6.00	37.55	41.40	45.94	51.30	57.61	64.93	73.25	82.35
6.50	40.08	44.02	48.63	53.99	60.18	67.25	75.14	83.63
7.00	42.55	46.57	51.21	56.54	62.62	69.44	76.93	84.89
7.50	44.97	49.05	53.71	58.99	64.94	71.51	78.64	86.13
8.00	47.35	51.47	56.13	61.35	67.16	73.50	80.28	87.35
8.50	49.68	53.84	58.48	63.63	69.29	75.41	81.88	88.56
9.00	51.98	56.15	60.77	65.85	71.36	77.26	83.44	89.77
9.50	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
10.00	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
10.50	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
11.00	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
11.50	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
12.00	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
12.50	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
13.00	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
13.50	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
14.00	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
14.50	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00
15.00	52.44	56.61	61.23	66.28	71.77	77.62	83.74	90.00

TERRACE CUT ABOVE BENCH HEIGHT OF 9.100001

ADVANCE AS A FUNCTION OF HEIGHT AND FRONT SLOPE ANGLE FOR THE O&K SH 630

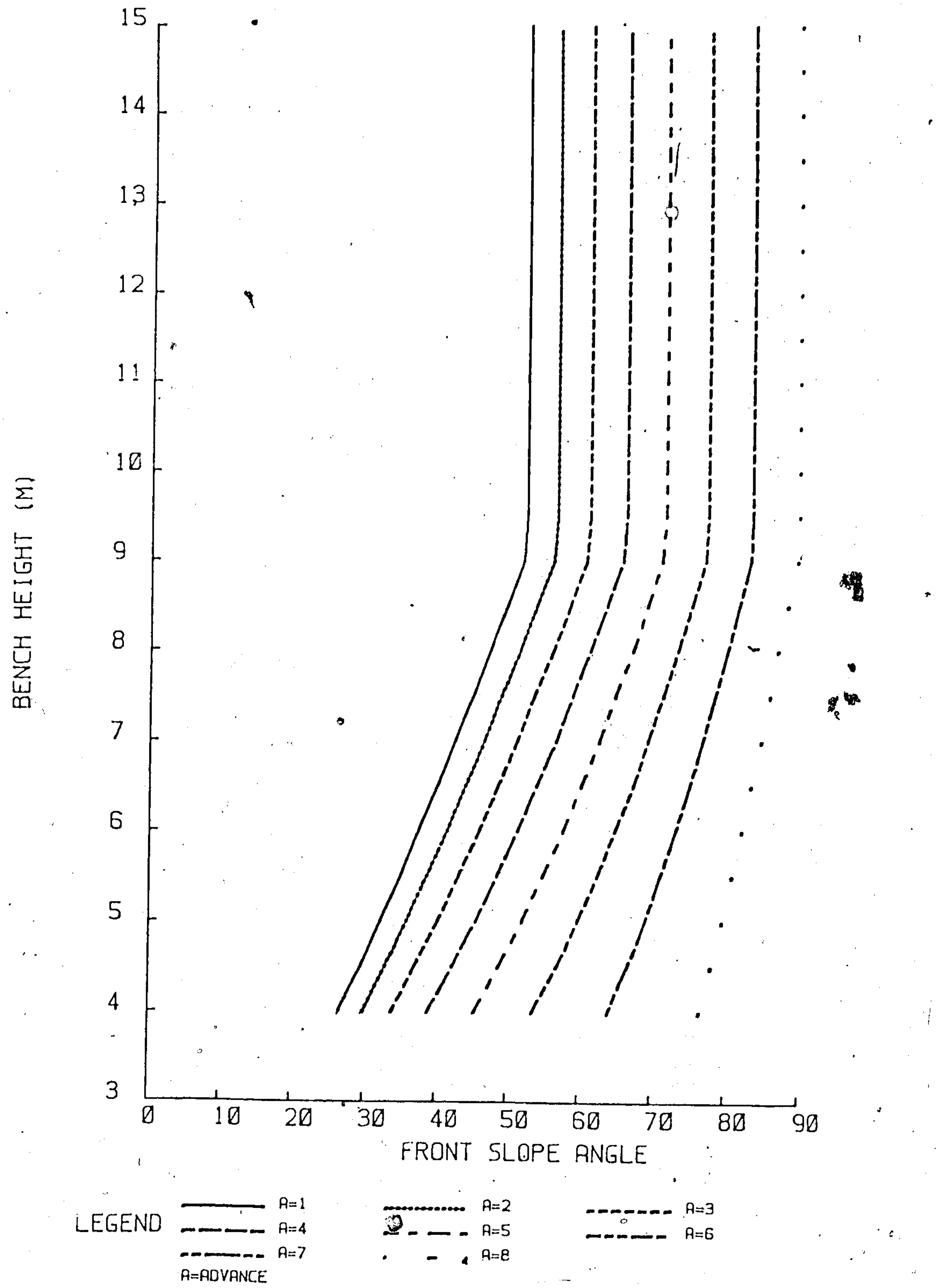
'A' IS ADVANCE @ FRONT SLOPE ANGLE
NOTE: FOR DROPPING CUT

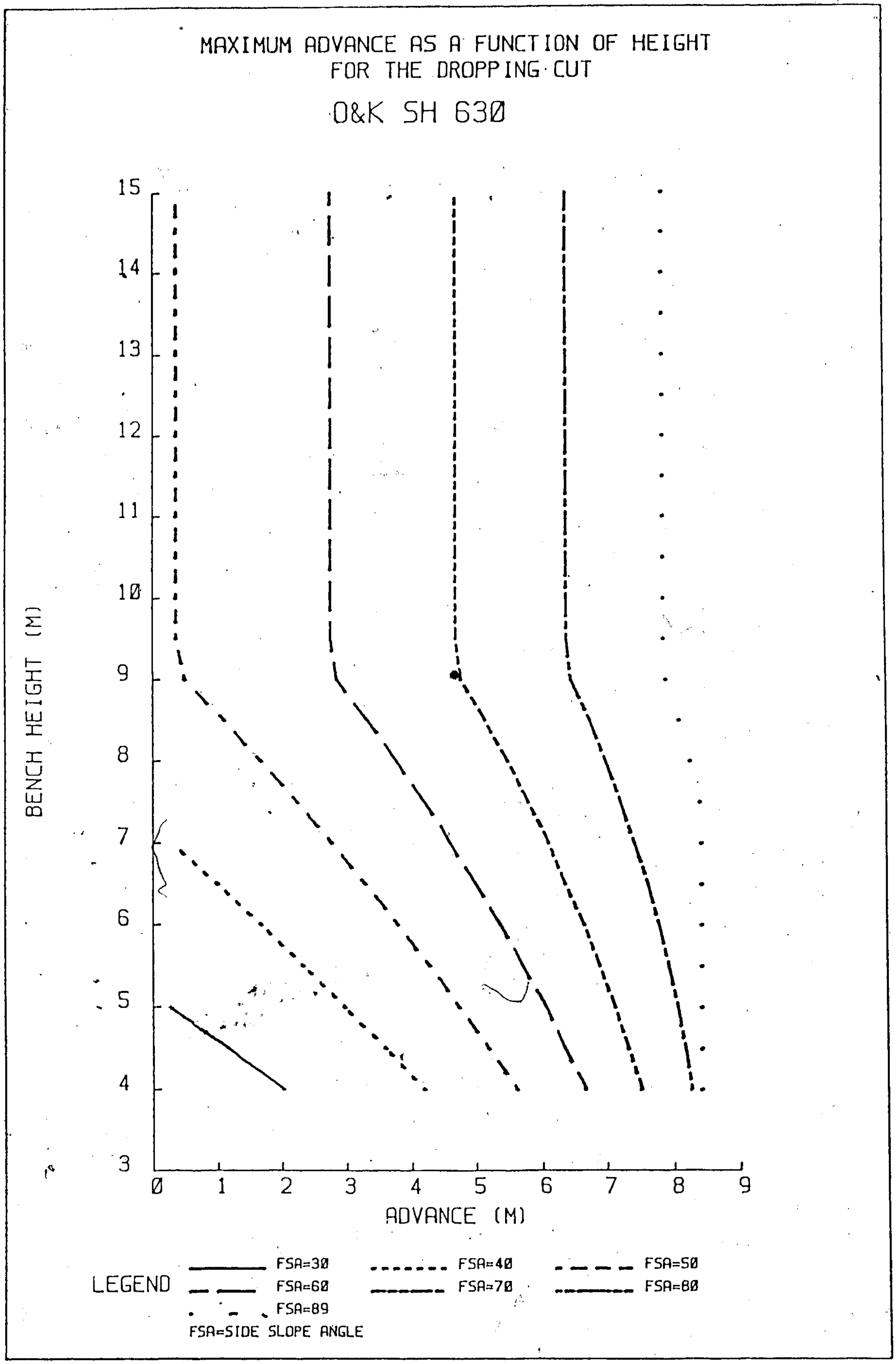
HEIGHT	A@30	A@40	A@50	A@60	A@70	A@80	A@89
4.00	2.03	4.19	5.60	6.64	7.50	8.25	8.40
4.50	1.15	3.58	5.17	6.34	7.31	8.15	8.40
5.00	0.25	2.96	4.72	6.03	7.10	8.03	8.40
5.50	0.00	2.31	4.25	5.69	6.87	7.90	8.40
6.00	0.00	1.66	3.77	5.34	6.62	7.75	8.40
6.50	0.00	0.98	3.27	4.97	6.36	7.58	8.40
7.00	0.00	0.28	2.75	4.58	6.08	7.39	8.40
7.50	0.00	0.00	2.21	4.18	5.78	7.18	8.38
8.00	0.00	0.00	1.66	3.75	5.46	6.96	8.23
8.50	0.00	0.00	1.08	3.31	5.12	6.71	8.06
9.00	0.00	0.00	0.48	2.84	4.76	6.45	7.88
9.50	0.00	0.00	0.36	2.74	4.69	6.39	7.84
10.00	0.00	0.00	0.36	2.74	4.69	6.39	7.84
10.50	0.00	0.00	0.36	2.74	4.69	6.39	7.84
11.00	0.00	0.00	0.36	2.74	4.69	6.39	7.84
11.50	0.00	0.00	0.36	2.74	4.69	6.39	7.84
12.00	0.00	0.00	0.36	2.74	4.69	6.39	7.84
12.50	0.00	0.00	0.36	2.74	4.69	6.39	7.84
13.00	0.00	0.00	0.36	2.74	4.69	6.39	7.84
13.50	0.00	0.00	0.36	2.74	4.69	6.39	7.84
14.00	0.00	0.00	0.36	2.74	4.69	6.39	7.84
14.50	0.00	0.00	0.36	2.74	4.69	6.39	7.84
15.00	0.00	0.00	0.36	2.74	4.69	6.39	7.84

TERRACE CUT ABOVE BENCH HEIGHT OF 9.100001

MINIMUM OVERALL FRONT SLOPE ANGLE AS A FUNCTION OF HEIGHT FOR THE DROPPING CUT

O&K SH 630




MAXIMUM ADVANCE AS A FUNCTION OF HEIGHT
FOR THE DROPPING CUT
O&K SH 630
BENCH HEIGHT (M)
ADVANCE (M)
3
4
5
6
7
8
9
10
11
12
13
14
15
0
1
2
3
4
5
6
7
8
9
LEGEND
FSA=30
FSA=40
FSA=50
FSA=60
FSA=70
FSA=80
FSA=89
FSA=SIDE SLOPE ANGLE

APPENDIX II-5

RANGE OF SIDE SLOPE ANGLES AS A FUNCTION OF HEIGHT FOR THE O&K SH 630

NOTE: DROPPING CUT, MODEL C
MAXIMUM SLEW ANGLE IS 70
VERTICAL WHEEL FREE ANGLE IS 59

HEIGHT	MINSSA	MAXSSA
4.00	25.03	77.43
4.50	27.74	76.06
5.00	30.37	75.49
5.50	32.94	74.89
6.00	35.44	74.23
6.50	37.89	73.57
7.00	40.28	72.95
7.50	42.62	72.24
8.00	44.93	71.56
8.50	47.20	70.88
9.00	49.43	70.17
9.50	49.87	69.22
10.00	49.87	68.21
10.50	49.87	67.17
11.00	48.62	66.11
11.50	49.12	65.06
12.00	49.80	65.59
12.50	50.62	65.02
13.00	51.55	64.70
13.50	51.55	64.70
14.00	51.55	64.70
14.50	51.55	64.70
15.00	51.55	64.70

TERRACE CUT IS USED ABOVE A BENCH HEIGHT OF 9.100001

RANGE OF SIDE SLOPE ANGLES AS A FUNCTION OF HEIGHT FOR THE O&K SH 630

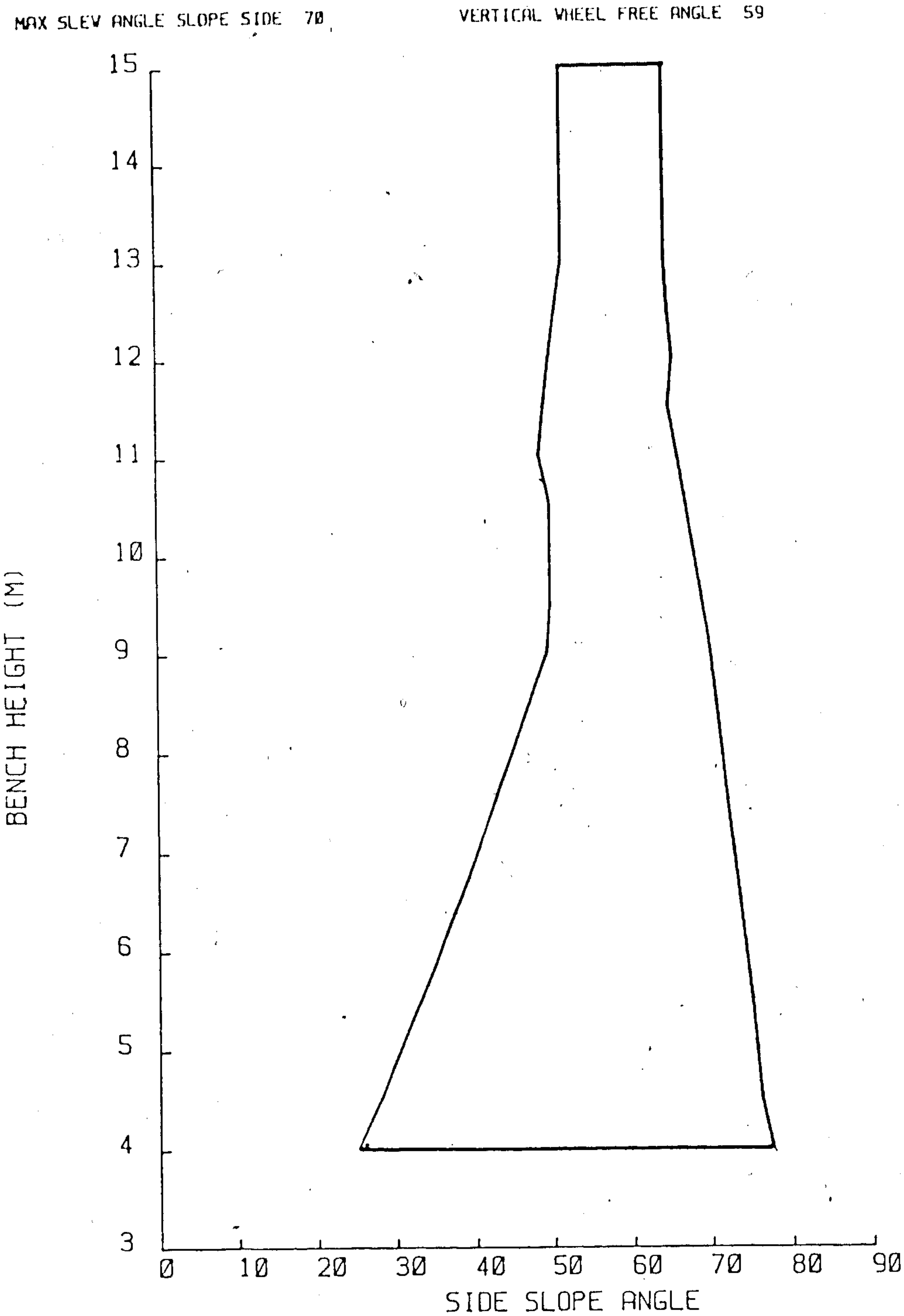
NOTE: DROPPING CUT, MODEL C
MAXIMUM SLEW ANGLE IS 90
VERTICAL WHEEL FREE ANGLE IS 59

HEIGHT	MINSSA	MAXSSA
4.00	22.83	82.11
4.50	25.37	82.53
5.00	27.85	83.27
5.50	30.29	84.96
6.00	32.68	84.32
6.50	35.03	81.92
7.00	37.35	79.72
7.50	39.64	77.99
8.00	41.90	76.76
8.50	44.14	75.58
9.00	46.36	74.45
9.50	46.80	73.83
10.00	46.80	73.69
10.50	45.13	73.29
11.00	45.43	72.84
11.50	45.97	72.39
12.00	46.68	72.07
12.50	47.53	72.40
13.00	48.48	72.18
13.50	48.48	72.18
14.00	48.48	72.18
14.50	48.48	72.18
15.00	48.48	72.18

TERRACE CUT IS USED ABOVE A BENCH HEIGHT OF 9.100001

RANGE OF SIDE SLOPE ANGLES AS A FUNCTION OF HEIGHT
FOR THE DROPPING CUT (MODEL C)

O&K SH 630

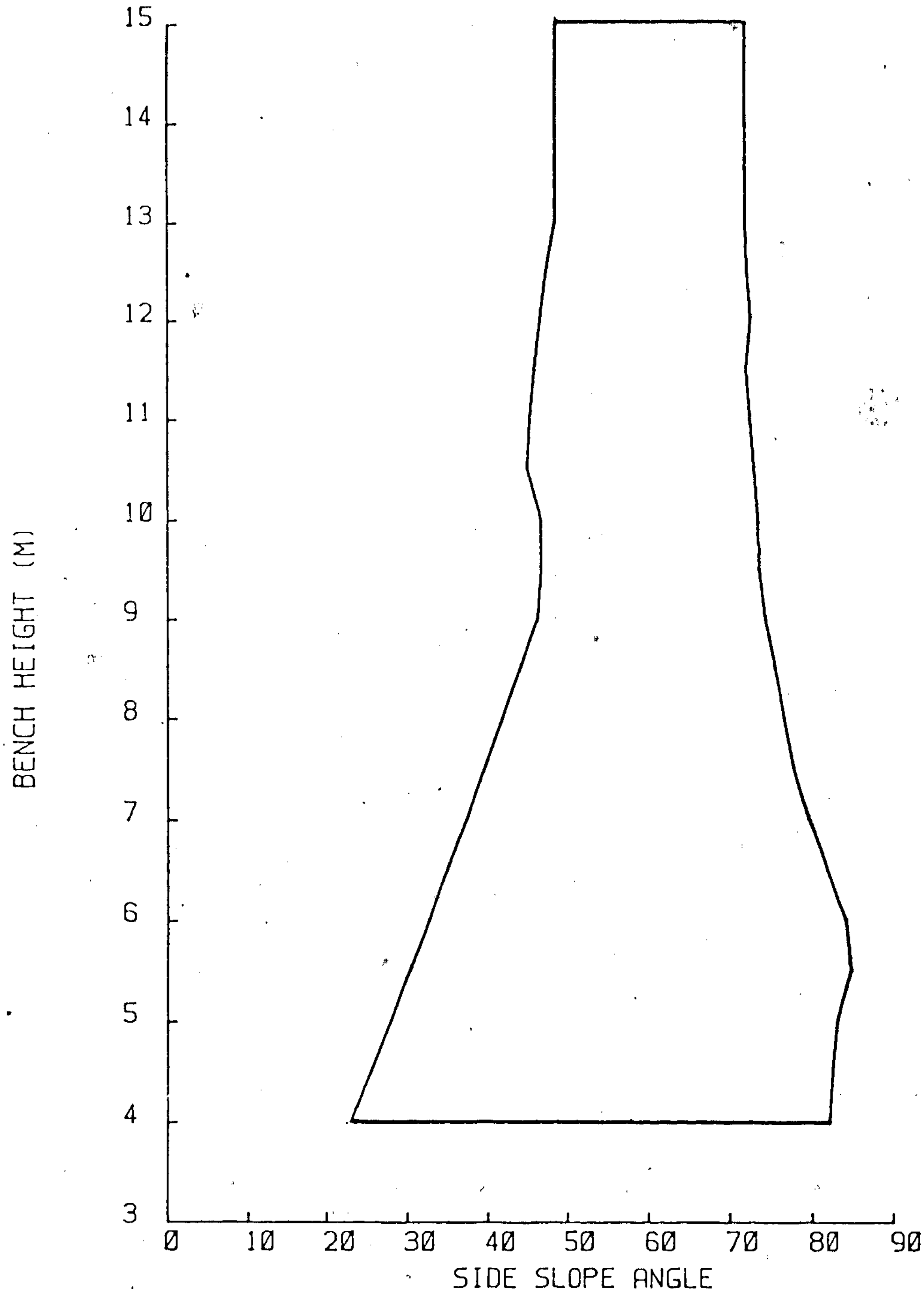


NOTE: A SIDE SLOPE ANGLE OF 90 DEGREES CAN ALWAYS BE FORMED

RANGE OF SIDE SLOPE ANGLES AS A FUNCTION OF HEIGHT
FOR THE DROPPING CUT (MODEL C)

O&K SH 630

MAX SLEV ANGLE SLOPE SIDE 90 VERTICAL VHEEL FREE ANGLE 59



NOTE: A SIDE SLOPE ANGLE OF 90 DEGREES CAN ALWAYS BE FORMED

APPENDIX II-6

MAXIMUM WIDTH OF CUT AS A FUNCTION OF HEIGHT AND SIDE SLOPE ANGLE FOR THE O&K SH 630

NOTE: MAXIMUM SLEW ANGLE ON SIDE SLOPE SIDE IS 70
NOTE: MAXIMUM SLEW ANGLE ON PIT SIDE IS 30
NOTE: FOR DROPPING CUT
NOTE: 'W' IS THE CUT WIDTH @ THE SIDE SLOPE ANGLE

HEIGHT	W@30	W@40	W@50	W@60	W@70	W@80	W@89
4.00	17.32	19.48	21.04	22.34	23.53	24.70	25.79
4.50	0.00	18.87	20.61	22.04	23.34	24.60	25.77
5.00	0.00	18.25	20.17	21.73	23.13	24.48	25.73
5.50	0.00	17.61	19.70	21.40	22.91	24.35	25.68
6.00	0.00	16.95	19.22	21.05	22.66	24.21	25.61
6.50	0.00	0.00	18.73	20.68	22.41	24.04	25.53
7.00	0.00	0.00	18.22	20.30	22.13	23.86	25.43
7.50	0.00	0.00	17.69	19.90	21.84	23.66	25.31
8.00	0.00	0.00	17.14	19.48	21.53	23.44	25.17
8.50	0.00	0.00	16.57	19.05	21.20	23.21	25.01
9.00	0.00	0.00	15.98	18.59	20.85	22.95	24.84
9.50	0.00	0.00	0.00	18.27	20.63	22.83	24.79
10.00	0.00	0.00	0.00	18.06	20.50	22.77	24.79
10.50	0.00	0.00	0.00	18.04	20.49	22.76	24.79
11.00	0.00	0.00	0.00	18.03	20.48	22.75	24.79
11.50	0.00	0.00	0.00	17.99	20.47	22.75	24.78
12.00	0.00	0.00	0.00	17.89	20.45	22.74	24.78
12.50	0.00	0.00	0.00	17.73	20.39	22.74	24.78
13.00	0.00	0.00	0.00	17.50	20.27	22.71	24.78
13.50	0.00	0.00	0.00	17.50	20.27	22.71	24.78
14.00	0.00	0.00	0.00	17.50	20.27	22.71	24.78
14.50	0.00	0.00	0.00	17.50	20.27	22.71	24.78
15.00	0.00	0.00	0.00	17.50	20.27	22.71	24.78

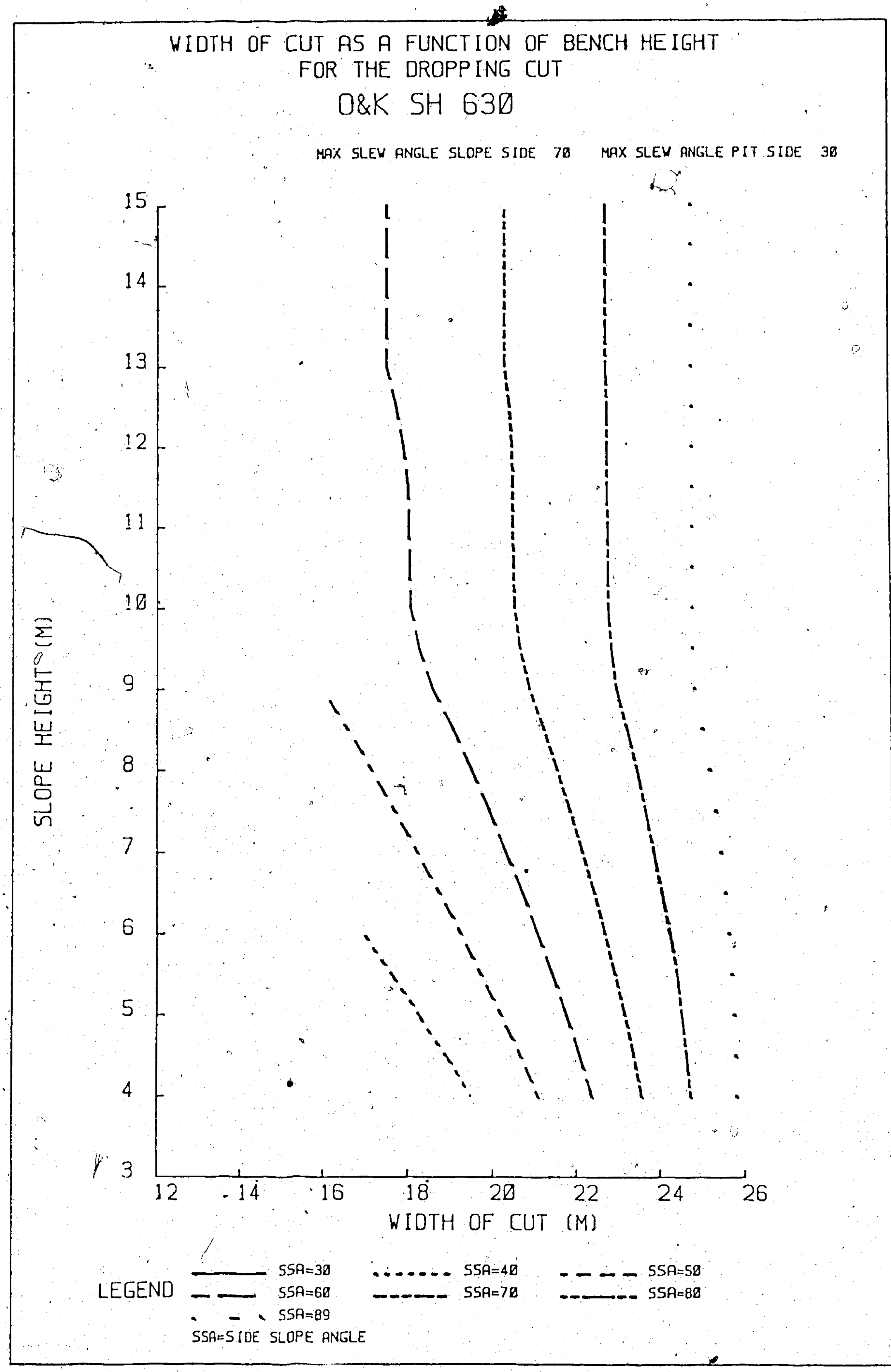
TERRACE CUT IS USED ABOVE BENCH HEIGHT OF 9.100001

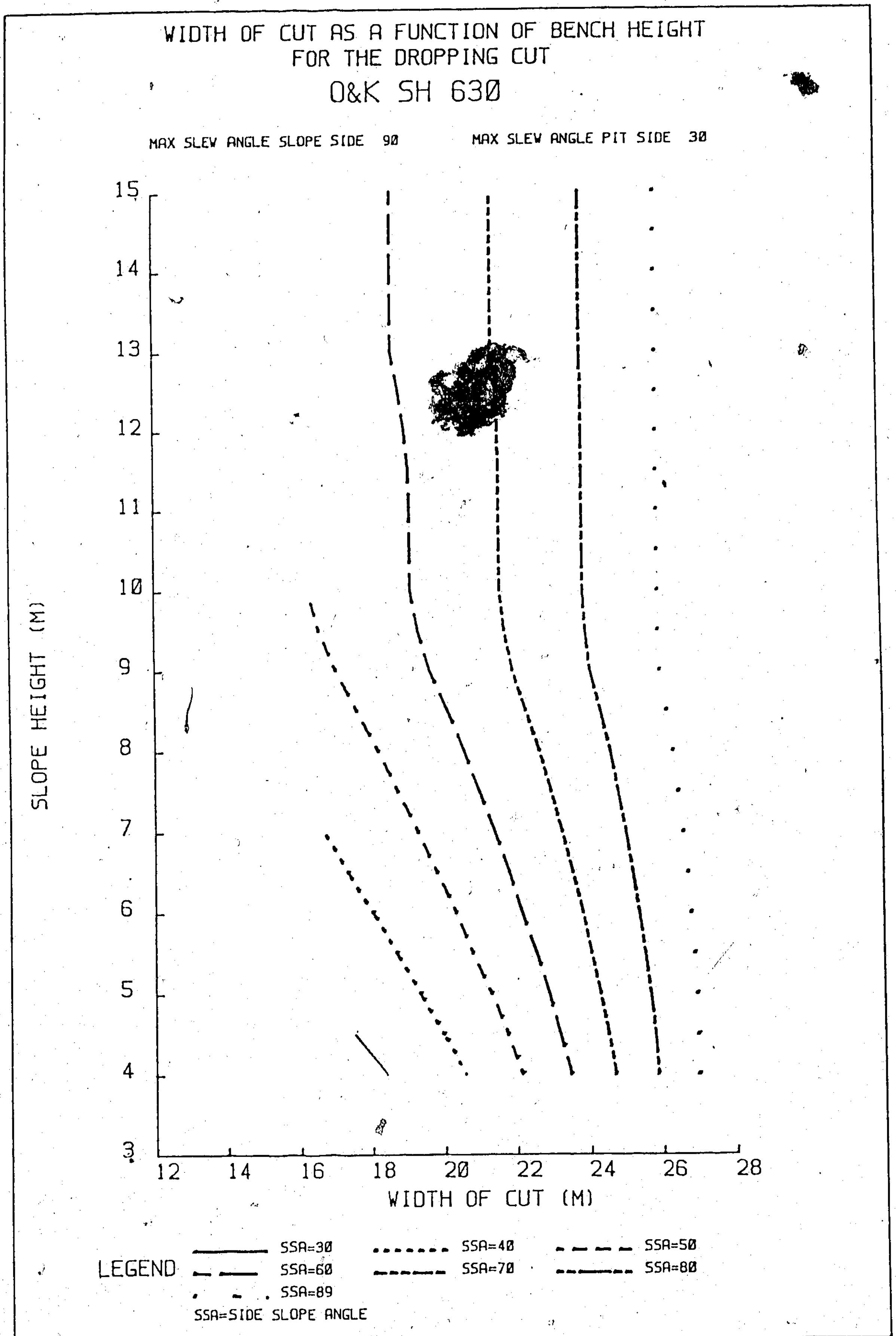
MAXIMUM WIDTH OF CUT AS A FUNCTION OF HEIGHT AND SIDE SLOPE ANGLE FOR THE O&K SH 630

NOTE: MAXIMUM SLEW ANGLE ON SIDE SLOPE SIDE IS 90
NOTE: MAXIMUM SLEW ANGLE ON PIT SIDE IS 30
NOTE: FOR DROPPING CUT
NOTE: 'W' IS THE CUT WIDTH @ THE SIDE SLOPE ANGLE

HEIGHT	W@30	W@40	W@50	W@60	W@70	W@80	W@89
4.00	18.39	20.55	22.13	23.45	24.66	25.85	26.97
4.50	17.52	19.95	21.70	23.15	24.46	25.75	26.95
5.00	0.00	19.32	21.25	22.83	24.25	25.63	26.91
5.50	0.00	18.68	20.79	22.50	24.03	25.50	26.86
6.00	0.00	18.02	20.30	22.14	23.78	25.35	26.79
6.50	0.00	17.35	19.80	21.77	23.52	25.18	26.70
7.00	0.00	16.65	19.28	21.39	23.24	24.99	26.59
7.50	0.00	0.00	18.75	20.98	22.94	24.79	26.46
8.00	0.00	0.00	18.19	20.55	22.62	24.56	26.32
8.50	0.00	0.00	17.61	20.11	22.28	24.32	26.15
9.00	0.00	0.00	17.02	19.64	21.92	24.05	25.96
9.50	0.00	0.00	16.56	19.31	21.70	23.92	25.92
10.00	0.00	0.00	16.26	19.11	21.57	23.86	25.91
10.50	0.00	0.00	0.00	19.11	21.57	23.86	25.91
11.00	0.00	0.00	0.00	19.11	21.57	23.86	25.91
11.50	0.00	0.00	0.00	19.10	21.57	23.86	25.91
12.00	0.00	0.00	0.00	19.01	21.57	23.86	25.91
12.50	0.00	0.00	0.00	18.85	21.52	23.86	25.91
13.00	0.00	0.00	0.00	18.63	21.40	23.84	25.91
13.50	0.00	0.00	0.00	18.63	21.40	23.84	25.91
14.00	0.00	0.00	0.00	18.63	21.40	23.84	25.91
14.50	0.00	0.00	0.00	18.63	21.40	23.84	25.91
15.00	0.00	0.00	0.00	18.63	21.40	23.84	25.91

TERRACE CUT IS USED ABOVE BENCH HEIGHT OF 9.100001


WIDTH OF CUT AS A FUNCTION OF BENCH HEIGHT
FOR THE DROPPING CUT
O&K SH 630
MAX SLEW ANGLE SLOPE SIDE 70 MAX SLEW ANGLE PIT SIDE 30
SLOPE HEIGHT (M)
3
4
5
6
7
8
9
10
11
12
13
14
15
WIDTH OF CUT (M)
12
14
16
18
20
22
24
26
LEGEND
SSA=30
SSA=40
SSA=50
SSA=60
SSA=70
SSA=80
SSA=89
SSA=SIDE SLOPE ANGLE


WIDTH OF CUT AS A FUNCTION OF BENCH HEIGHT
FOR THE DROPPING CUT
O&K SH 630
MAX SLEV ANGLE SLOPE SIDE 90
MAX SLEV ANGLE PIT SIDE 30
SLOPE HEIGHT (M)
3
4
5
6
7
8
9
10
11
12
13
14
15
WIDTH OF CUT (M)
12
14
16
18
20
22
24
26
28
LEGEND
SSA=30
SSA=40
SSA=50
SSA=60
SSA=70
SSA=80
SSA=89
SSA=SIDE SLOPE ANGLE

APPENDIX III

Height	Slew Angle Slope Side	Slew Angle Pit Side	Dist X1
12.6	76.14	16.00	0.00
8.4	51.10	24.45	2.23
4.2	41.60	35.50	3.21

TABLE T1 Slew angles and distance the BWE load boom pivot point must move to form the slope model T1

Height	Slew Angle Slope Side	Slew Angle Pit Side	Dist X1
9.10	70.00	8.71	0.00
8.35	63.32	10.25	0.43
7.60	58.38	11.79	1.35
6.85	54.40	13.33	1.96
6.10	51.04	14.88	2.53
5.35	48.13	16.46	3.05
4.60	45.57	18.09	3.54
3.85	43.27	19.77	3.99
3.10	41.18	21.52	4.39
2.35	39.27	23.36	4.76
1.60	37.51	25.32	5.09
0.85	35.88	27.41	5.38
0.10	34.36	29.68	5.63

TABLE D1 Slew angles and distance the BWE load boom pivot point must move to form the slope model D1

Height	Slew Angle	Dist X1
9.10	70.00	0.00
8.35	63.32	1.01
7.60	58.38	1.98
6.85	54.40	2.91
6.10	51.04	3.79
5.35	48.13	4.64
4.60	45.57	5.44
3.85	43.27	6.21
3.10	41.18	6.93
2.35	39.27	7.62
1.60	37.51	8.26
0.85	35.88	8.87
0.10	34.36	9.43

TABLE D2-A Slew angle and distance the BWE load boom pivot point must move to form the slope model D2-A

Height	Slew Angle	Dist X1
9.10	70.00	0.00
8.35	64.73	1.01
7.60	60.79	1.98
6.85	57.64	2.91
6.10	55.03	3.79
5.35	52.82	4.64
4.60	50.92	5.44
3.85	49.28	6.21
3.10	47.85	6.93
2.35	46.61	7.62
1.60	45.55	8.26
0.85	44.64	8.87
0.10	43.88	9.43

TABLE D3-A Slew angle and distance the BWE load boom pivot point must move to form the slope model D3-A

Height	Slew Angle	Dist X1
9.10	70.00	0.00
8.35	66.05	1.01
7.60	63.08	1.98
6.85	60.76	2.91
6.10	58.90	3.79
5.35	57.40	4.64
4.60	56.20	5.44
3.85	55.25	6.21
3.10	54.53	6.93
2.35	54.02	7.62
1.60	53.71	8.26
0.85	53.62	8.87
0.10	53.74	9.43

TABLE D4-A Slew angle and distance the BWE load boom pivot point must move to form the slope model D4-A

Height	Slew Angle	Dist X1
9.10	65.00	0.00
8.35	60.64	1.01
7.60	57.20	1.98
6.85	54.37	2.91
6.10	51.98	3.79
5.35	49.93	4.64
4.60	48.15	5.44
3.85	46.60	6.21
3.10	45.24	6.93
2.35	44.05	7.62
1.60	43.01	8.26
0.85	42.11	8.87
0.10	41.35	9.43

TABLE D5-A Slew angle and distance the BWE load boom pivot point must move to form the slope model D5-A

Height	Slew Angle	Dist X1
6.00	89.00	0.00
5.25	77.52	0.52
4.50	72.87	1.00
3.75	69.62	1.44
3.00	67.15	1.85
2.25	65.22	2.21
1.50	[illegible]3.71	2.53
0.75	62.55	2.82
0.00	61.71	3.06

TABLE D1-B Slew angle and distance the BWE load boom pivot point must move to form the slope model D1-B

Height	Slew Angle	Dist X1
6.00	89.00	0.00
5.25	80.85	0.52
4.50	77.78	1.00
3.75	75.92	1.44
3.00	74.80	1.85
2.25	74.26	2.21
1.50	74.26	2.53
0.75	74.83	2.82
0.00	76.06	3.06

TABLE D2-B Slew angle and distance the BWE load boom pivot point must move to form the slope model D2-B

Height	Slew Angle	Dist X1
6.00	89.00	0.00
5.25	81.83	0.52
4.50	79.26	1.00
3.75	77.87	1.44
3.00	77.24	1.85
2.25	77.28	2.21
1.50	78.01	2.53
0.75	79.61	2.82
0.00	82.72	3.06

TABLE D3-B Slew angle and distance the BWE load boom pivot point must move to form the slope model D3-B

Height	Slew Angle	Dist X1
9.10	70.00	0.00
8.35	61.67	0.70
7.60	55.62	1.35
6.85	50.73	1.96
6.10	46.57	2.53
5.35	42.91	3.05
4.60	39.62	3.54
3.85	36.61	3.99
3.10	33.82	4.39
2.35	31.19	4.76
1.60	28.70	5.09
0.85	26.31	5.38
0.10	23.99	5.63
0.00	23.69	5.70

TABLE D1-C Slew angles and distance the BWE load boom pivot point must move to form the slope model D1-C

Height	Slew Angle	Dist X1
9.10	70.00	0.00
8.35	63.32	0.47
7.60	58.38	0.89
6.85	54.39	1.26
6.10	51.04	1.60
5.35	48.13	1.89
4.60	45.57	2.15
3.85	43.27	2.36
3.10	41.18	2.54
2.35	39.26	2.68
1.60	37.51	2.77
0.85	35.88	2.83
0.10	34.36	2.84
0.00	34.17	2.84

TABLE D2-C Slew angles and distance the BWE load boom pivot point must move to form the slope model D2-C

Height	Slew Angle	Dist Xl
9.10	70.00	0.00
8.35	65.45	0.47
7.60	61.90	0.89
6.85	58.93	1.26
6.10	56.38	1.60
5.35	54.14	1.89
4.60	52.16	2.15
3.85	50.39	2.36
3.10	48.80	2.54
2.35	47.37	2.68
1.60	46.04	2.77
0.85	44.91	2.83
0.10	43.88	2.84
0.00	43.79	2.84

TABLE D3-C Slew angles and distance the BWE load boom pivot point must move to form the slope model D3-C