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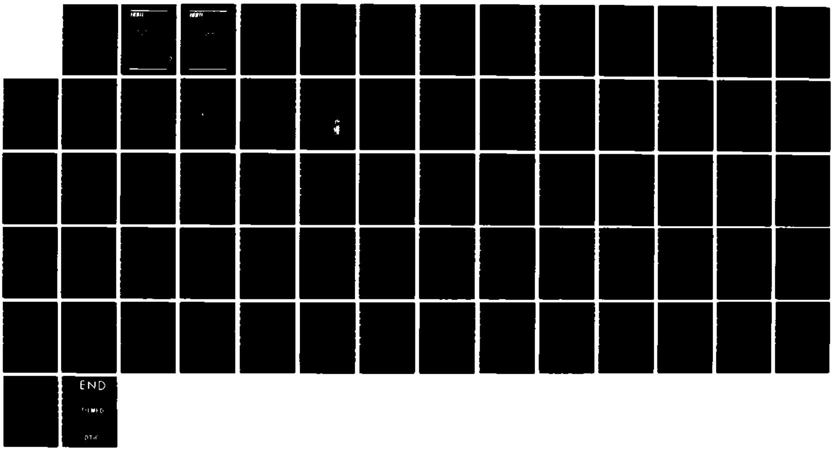

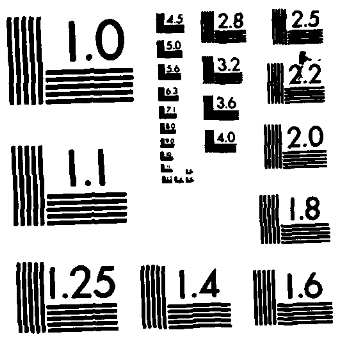

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AD-A159 444

Countermine Combat Systems Analysis

(Mine Plow Evaluation Module)

PREPARED FOR THE U.S. ARMY BELVOIR RESEARCH AND DEVELOPMENT CENTER, FORT BELVOIR, VIRGINIA 22060-5166

SEPTEMBER 15, 1985 BDM/W-85-0785-TR

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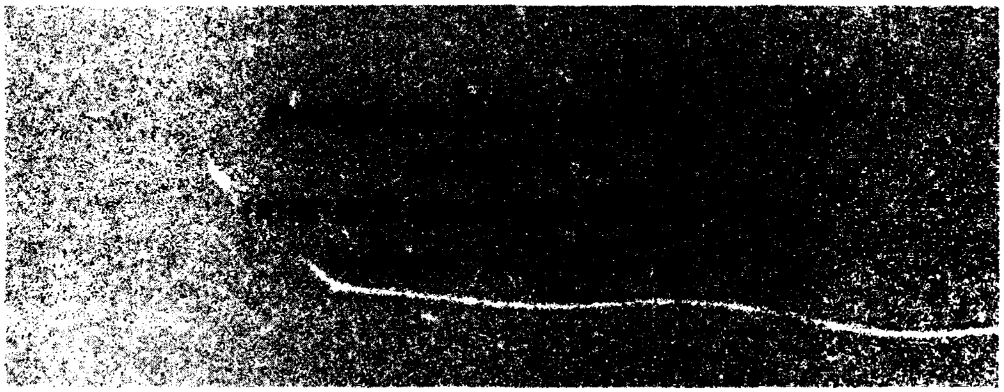

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This report summarizes the results of tasks conducted to provide the Engineer Support Laboratory with a low cost evaluation model to be used in the assessment of countermine concept alternatives. The model is microcomputer-based and supported by a commercial software package which provides ease of use, rapid computational abilities, and useful graphics features.

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FOREWORD

The BDM Corporation, 7915 Jones Branch Drive, McLean, Virginia 22102, is pleased to present this draft final report to the U.S. Army Belvoir Research and Development Center, Fort Belvoir, Virginia 22060-5166. This document, entitled, "Countermine Combat Systems Analysis (Mine Plow Evaluation Module)," summarizes the results of tasks conducted to provide the Engineer Support Laboratory with a low cost, microcomputer-based evaluation model to be used in the assessment of countermine concept alternatives. A commercial software package was used to develop and operate the methodology in order to demonstrate the computational abilities, graphics features, and user-friendliness of such products.

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CHAPTER I
INTRODUCTION

A. GENERAL

The mine plow assessment model is an evaluation tool which enables the user to perform rapid computations in an easy-to-learn environment. This software package is designed to complement a family of countermine evaluation software systems which address, the entire spectrum of operations from detection to neutralization. Each methodology is capable of predicting the performance of a designated countermine strategy or system within a specified scenario.

Figure I-1 illustrates the method by which the evaluation methodology performs a simulation of mine plow performance. The model requires several inputs which describe the mine field, mines, plow mechanism, and the specific scenario in which the system is to be analyzed. A traverse of the mine field by the mine plow is then simulated, followed by the passage of a specified number of trailing vehicles. Results are given for the probability of survival for the plow unit, trailing vehicle, and formation as a whole. The amount of time required to clear and traverse an area is also provided.

The mine plow evaluation methodology has been designed to operate on the IBM series of personal computers. The use of microcomputer based software for performance evaluation has proven to be an attractive course of action due to favorable cost, availability, and technical performance. The program operates in a spread sheet format within the Lotus 1-2-3 commercial software package. This software system was chosen to demonstrate the computational, graphical, and user-friendly capabilities which are commercially available at a low cost. Lotus 1-2-3 provides rapid computational capabilities and effective graphics output features to the user.

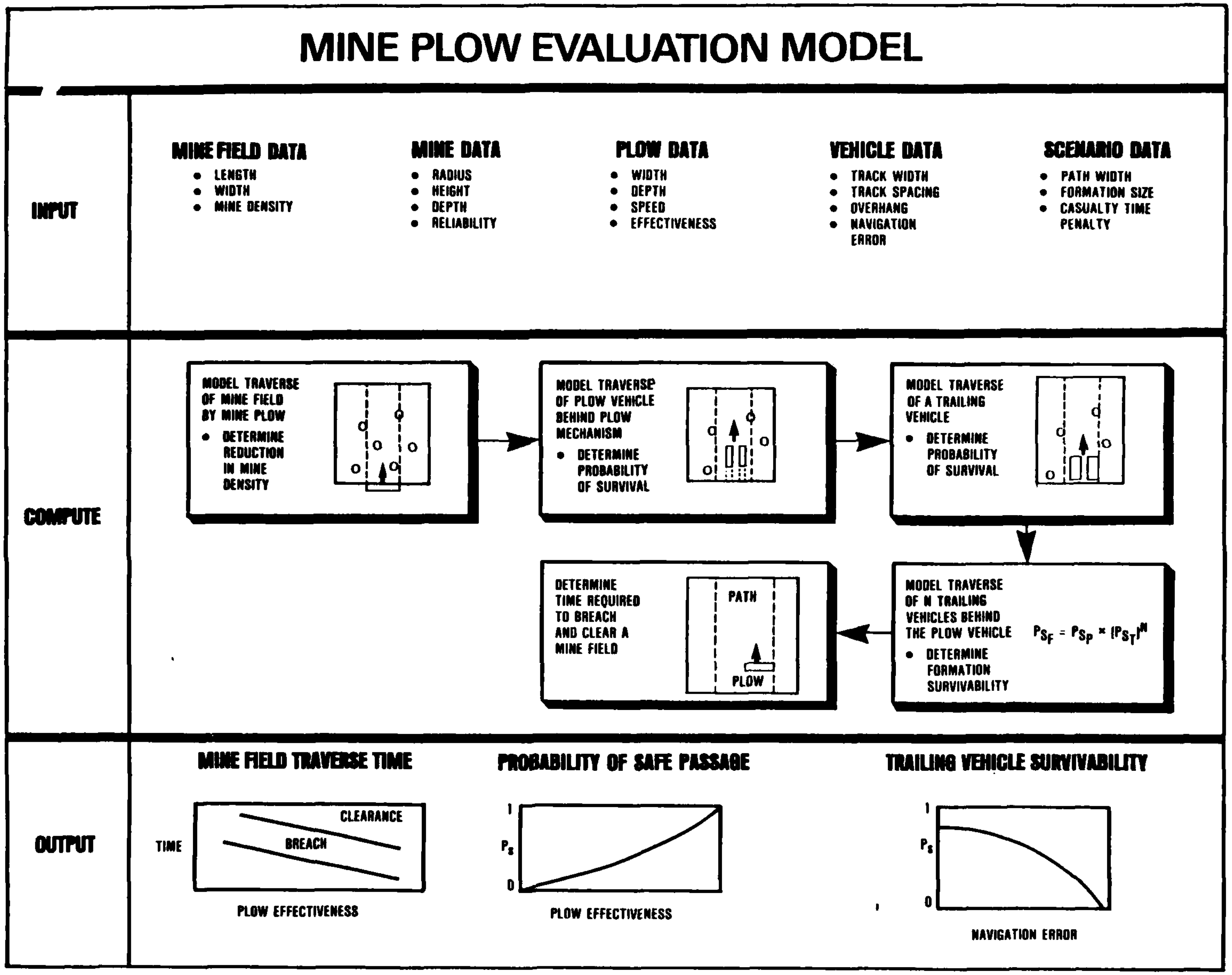


Figure I-1. Description of Mine Plow Evaluation Model

B. BACKGROUND

The Engineer Support Laboratory is engaged in numerous development programs to enhance the capability of U.S. forces to conduct countermine operations. These programs compete, within the Laboratory, for limited program resources. An example of one such program is the Mine Clearing Plow System (MCPS) which requires accelerated fielding at the User's direction. Three separate courses of action are being pursued concurrently to provide the M1 and M60 main battle tank with a mine clearing plow capability as soon as possible. Hence, it is imperative that the most promising initiatives be identified and pursued. The overall R&D program must also balance near term and long term development efforts to ensure a continuous improvement in force combat power. At present, no capability exists within the Laboratory to systematically evaluate alternative concepts and structure an overall program which balances development risks and limited resources against the technical estimates of the development system performance.

A requirement existed for a mine clearing plow performance evaluation model. This assessment methodology will be used to determine the technical worth of candidate systems through an objective simulation process. In this way a low-cost first estimate of the performance of each mine plow concept can be obtained.

C. OBJECTIVES

The objectives of this effort were as follows:

(1) To develop a software tool to support the evaluation of alternative research and development initiatives for mine clearance plow systems, and

(2) To design the evaluation tool to be low cost and to operate on a microcomputer-based system using a commercially available software support package.

D. TECHNICAL APPROACH

In order to accomplish the objectives of this program, the following tasks were performed:

(1) Determine which microcomputer system would be most suitable for this application,

(2) Establish operating specifications for the analysis methodology in order to determine the microcomputer hardware and software requirements,

(3) Determine analytical requirements for the evaluation model in order to define the inputs and computations required to perform the desired simulations,

(4) Define the desired outputs from the software which are needed in order to provide the user with an effective means of comparing the various candidate systems to be examined,

(5) Design useful formats for the methodology outputs to include graphical representations of the analysis results, and

(6) Develop the evaluation tool on the specified microcomputer system, ensuring an easy-to-use yet technically reliable product.

E. REPORT STRUCTURE

The following chapters in this document provide the reader with a detailed description of the mine plow assessment methodology.

Chapter II describes the inputs required by the model in order to perform the desired simulation and evaluation.

Chapter III presents an explanation of the various steps required in the simulation. The methods by which important results are obtained are described in this chapter.

Chapter IV provides a description of the outputs available from this model. The functions necessary to perform a parametric analysis using the mine plow simulation tool are presented. A summary is given of the steps required to generate graphical presentations to display the results of a parametric analysis.

Chapter V provides the reader with an example simulation of a mine plow system. Inputs and resulting outputs are shown, in addition to various graphical outputs from the data generated by the model.

Chapter VI presents a summary of the accomplishments of this program effort.

CHAPTER II

MODEL INPUTS

A. INTRODUCTION

The various input parameters required by the evaluation model can be grouped into the following areas of description:

(1) Mine field parameters,

(2) Mine parameters,

(3) Mine plow parameters,

(4) Trailing vehicle parameters, and

(5) Scenario parameters.

Each of the input sets listed above will be discussed in detail in the following sections.

B. MINE FIELD PARAMETERS

Figure II-1 shows the pertinent mine field characteristics which must be supplied to the model. The dimensions of the field must be included in order to determine the time required to clear a specific area. These dimensions, which are expressed in meters, determine the number of passes and the elapsed time for each clearing pass.

The mine density within the field is given in terms of the number of mines present per meter of front. This parameter determines the average number of mines contained in a meter-wide strip through the mine field in the direction of formation movement. Mine density is of critical importance to the model results and is one of the primary values to be varied in a parametric analysis.

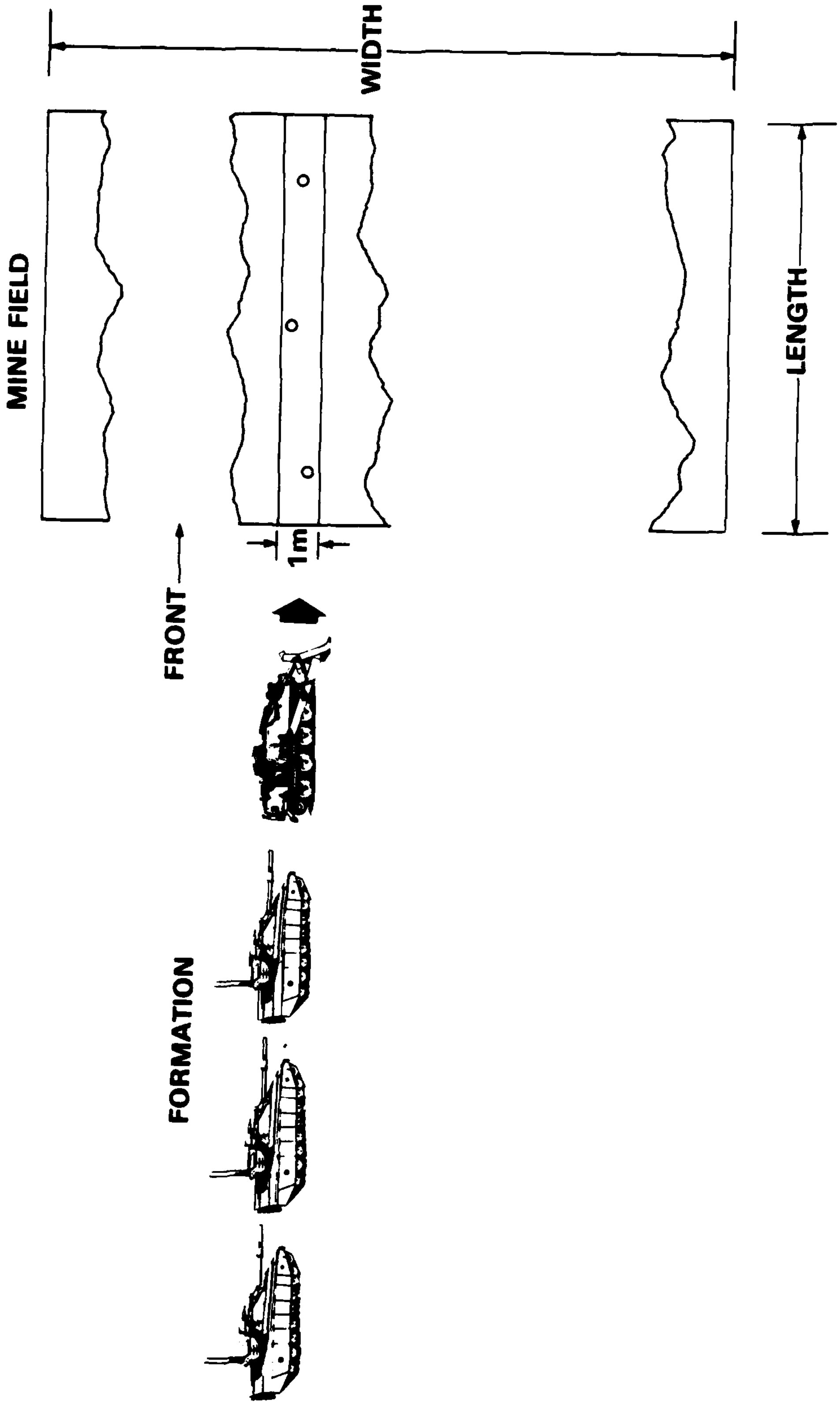


Figure II-1. Mine Field Inputs

C. MINE PARAMETERS

The mine plow assessment model treats the individual mines as bodies having dimensions rather than simplifying the calculations by using the point mass assumption. Each mine is assumed to be a cylinder with a known radius, measured in meters. The model is then able to consider the scenario where a vehicle track encounters part of a mine. In this manner, a vehicle does not have to encounter the center of a mine in order for the trigger mechanism to function.

The average depth of a mine, measured in meters from the surface down to the top of a mine, is an input to the model. In the case of an unburied mine, the depth can be zero or the height of the mine, expressed as a negative value.

The final mine parameter required is the probability of mine detonation given that it has been triggered by a vehicle. This parameter addresses the issue of mine reliability. If a value is not known for this input, then the conservative figure of 1.0 should be used.

D. MINE PLOW PARAMETERS

1. Introduction

The inputs describing the mine plow are divided into two groups. Those parameters which describe the actual plow mechanism are referred to as plow parameters. The plow vehicle parameters describe the vehicle which transports and operates the plow mechanism. The following sections describe each of these groups in detail.

2. Plow Parameters

Figure II-2 illustrates the inputs required to describe the plow mechanism. The plow depth is necessary to determine whether the plow will neutralize the mines present in the field. The scenario of a plow with too shallow a depth would result in an actual plow effectiveness of zero since no mines would be cleared. The plow depth is input in meters.

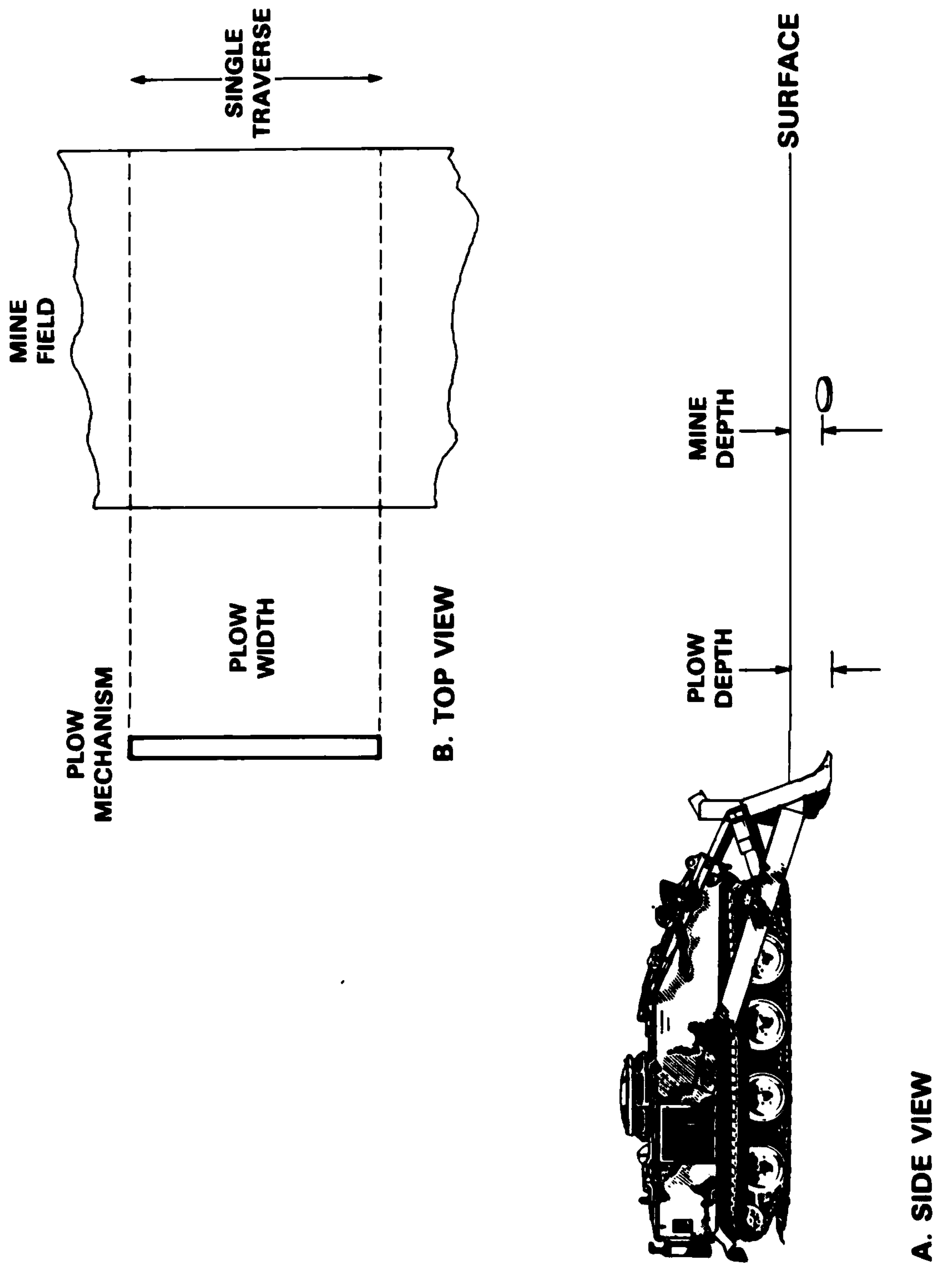


Figure II-2. Mine Plow Inputs

The plow width, also measured in meters, determines the number of traverses required to clear a specified path through the mine field using a single plow. This value effects the total clearing time.

An input not shown in Figure II-2 is the plow effectiveness. This parameter, which has a value from 0.0 to 1.0, determines the probability that the plow will remove or neutralize a mine which it physically encounters. This value is of great importance and should be a primary variable in a parametric analysis of mine plow performance.

3. Plow Vehicle Parameters

The plow vehicle parameters describe the relative locations and dimensions of the vehicle tracks with respect to the plow mechanism. Figure II-3 presents these inputs, all of which are measured in meters. The dimension T is the plow vehicle track width. The dimension S is the track spacing. The final dimension, D, is known as the plow overhang. This value represents the distance beyond the outside edge of a track which has been cleared by the plow mechanism. These values are important when combined with similar values for the trailing vehicles.

The plow vehicle speed, measured in meters per second, is a factor in determining the total time required to clear a specified area. This value is dependent on the type of vehicle used and, most importantly, on the plow depth.

E. TRAILING VEHICLE PARAMETERS

The trailing vehicle parameters are similar to those which describe the plow vehicle. Specifically, the track width, track spacing, and plow overhang beyond the tracks must be provided to the model. The plow overhang is measured assuming that the trailing vehicle is centered behind the mine plow.

Figure II-4 shows the trailing vehicle parameters. These values, as shown in the figure, are not necessarily identical to those of the plow vehicle. Both sets of input are important, because of the fact that the trailing vehicles are following the plow vehicle. Ideally, the trailing

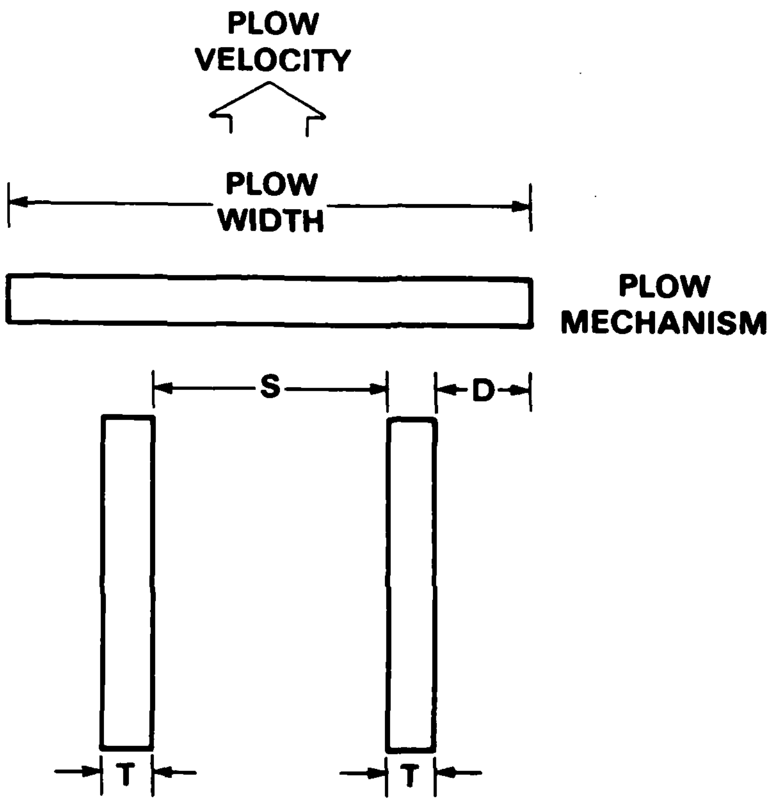


Figure II-3. Mine Plow Vehicle Inputs

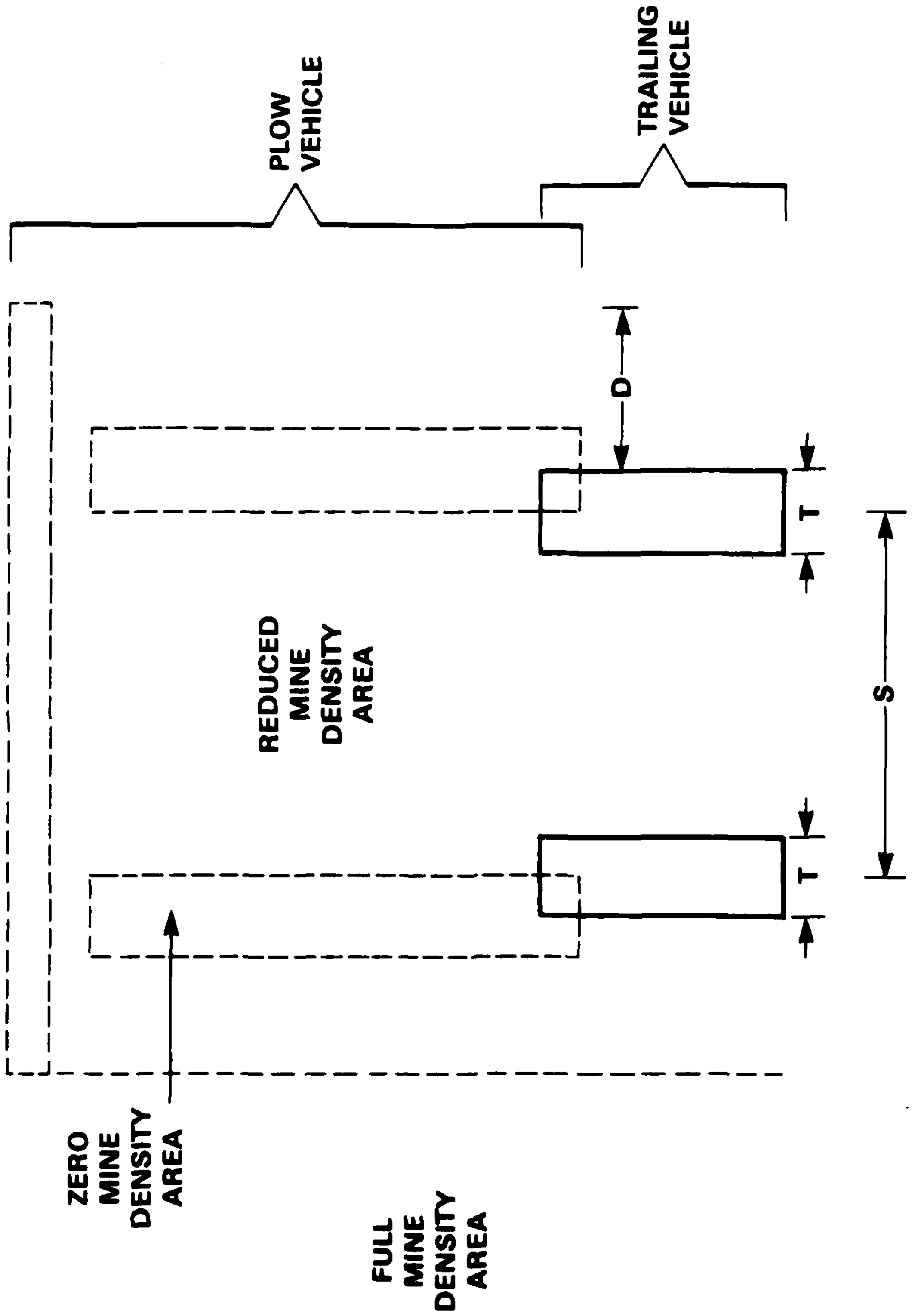


Figure II-4. Trailing Vehicle Inputs

vehicles would travel in the tracks left by the plow vehicle; however, this does not usually occur due to differing dimensions and maneuvering inaccuracies. When the trailing vehicles deviate from the plow tracks, they leave an area of zero mine density and enter an area of reduced or full mine density. This decreases the probability of survival for each trailing vehicle and the formation as a whole.

The probability that a trailing vehicle will not exactly follow the plow tracks is treated as a normal distribution. The standard deviation, which is a function of vehicle type and operator skills, must be input to the model. This value, like the other trailing vehicle parameters, is measured in meters.

F. SCENARIO PARAMETERS

The scenario parameters required by this model define the traverse of a mine field by a specified formation. The formation is defined by the total number of vehicles trailing the mine plow vehicle. The size of the path to be cleared through a mine field is defined by the path width. Each pass made by the plow to clear a certain width of the mine field adds to the total formation traversal time. An average casualty time penalty, in minutes, is given as the time required to remove or bypass a vehicle damaged by contact with an uncleared mine. This value is used together with the probability that a vehicle will be damaged as an addition to the total average time required to traverse a mine field.

CHAPTER III

MODEL DESCRIPTION

A. INTRODUCTION

The mine plow evaluation model is an easy-to-use analysis tool which was designed to operate on an IBM-PC personal computer using the Lotus 1-2-3 software package. The Lotus 1-2-3 package is best known for its spread sheet capabilities; however, it possesses excellent computational features as well. In addition, Lotus 1-2-3 provides valuable graphics capabilities which are useful for presentation of the model outputs.

This evaluation model performs a predicted value analysis to determine the probability of survival for the plow vehicle, the trailing vehicles, and the formation as a whole. The analysis procedure can be divided into the following modules:

(1) Mine clearance simulation,

(2) Plow vehicle survivability computation,

(3) Trailing vehicle survivability computation,

(4) Formation survivability computation, and

(5) Elapsed time computation.

Each of these procedures will be discussed individually in the following sections of this chapter.

B. MINE CLEARANCE SIMULATION

This section of the evaluation model simulates the passage of the mine plow mechanism through a specified mine field. The required inputs are the mine field density, the mine plow effectiveness, the plow depth, and the mine depth.

The first computation performed is a comparison of the plow and mine depths. If the individual mines are located at a depth greater than will be reached by the plow mechanism, then the mine plow will pass over the mines. The result is that the mine plow has an actual effectiveness of zero instead of the input value, since its traverse will not reduce the density of active mines in the path of the plow vehicle and trailing vehicles. If the plow depth is greater than the mine depth, then the mechanism will perform its mission. The actual plow effectiveness is equal to the input value for this case.

Figure III-1 illustrates the passage of a mine plow through a mine field. The scenario shown is for a plow mechanism with a depth greater than that of the mines. As the plow moves in the direction indicated, it reduces the density of active mines remaining in the path of the plow and trailing vehicles. The tracks of the mine plow vehicle have been included as an example. In this case, the mine plow has been assumed to possess an effectiveness of 67 percent. The passage of the plow will remove or neutralize two of every three mines that it encounters.

The final computation of this module is the determination of the mine field density in the region which has been traversed by the mine plow mechanism. The density subsequent to plowing is computed by multiplying the original mine field density by a reduction factor. The reduction factor is equal to one minus the actual plow effectiveness as determined earlier in this module. The new mine density is required as an input by the modules which determine survivabilities for the plow and trailing vehicles. These subprograms are described in the following two sections.

C. PLOW VEHICLE SURVIVABILITY

This part of the analysis simulates the passage of the mine plow vehicle through a mine field as it carries or operates the plow mechanism. Since it is probable that the effectiveness of the plow will be less than one, there is a possibility that the plow vehicle will be damaged or destroyed by an active mine. This loss would lead to a time delay caused

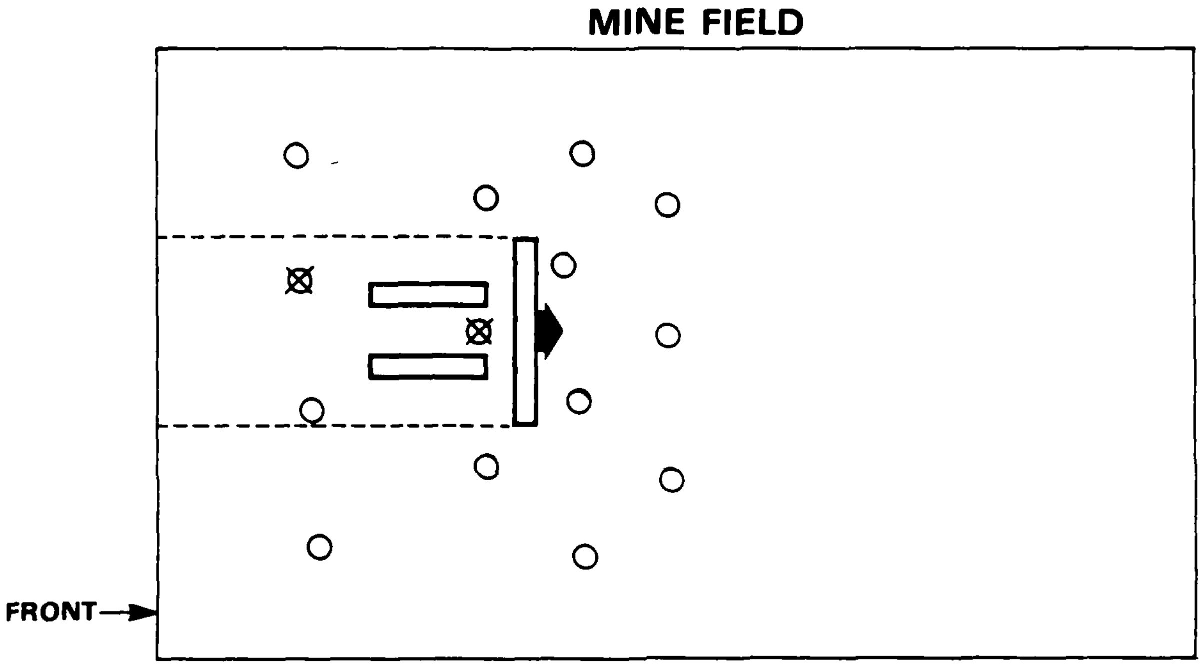


Figure III-1. Illustration of Mine Clearing Simulation by the preparation of another plow vehicle. The required inputs to this module are the width of the plow vehicle tracks and the reduced mine density subsequent to plowing which was determined in the previous subprogram.

Figure III-2 presents the passage of a vehicle behind the plow mechanism. The separation between the vehicle tracks and the plow mechanism has been exaggerated for the purposes of this illustration. It will be noted here that the plow vehicle and plow mechanism, even though they are actually combined in one unit, are evaluated in this model as individual pieces of equipment. This separation correctly addresses the fact that the performance of the plow vehicle is dependent upon the performance of the plow mechanism.

The probability that a plow vehicle will suffer a casualty due to a mine not neutralized by the plow mechanism is computed by the following formula:

$P_k = 2 \times T \times$ (Post-plowing mine density)

This value is dimensionless since the track width, T, is measured in meters and the mine density is expressed in units of number per meter of front. The reduced mine density is used in this calculation because the plow vehicle tracks are always within the area covered by the plow mechanism. During mine field passage by the trailing vehicles, a possibility exists that the tracks will be outside the cleared region. In this case, the original mine field density must be used to determine survivability.

The probability that the plow vehicle will safely pass through a cleared mine field is equal to one minus the probability of a plow vehicle casualty. In the course of a parametric analysis the formula shown above could result in a probability of kill greater than one. This would produce a negative probability of survival, which would cause errors later in the program; therefore, the probabilitv of plow vehicle casualty is restricted to values less than or equal to one. Values greater than one are reduced to 1.0.

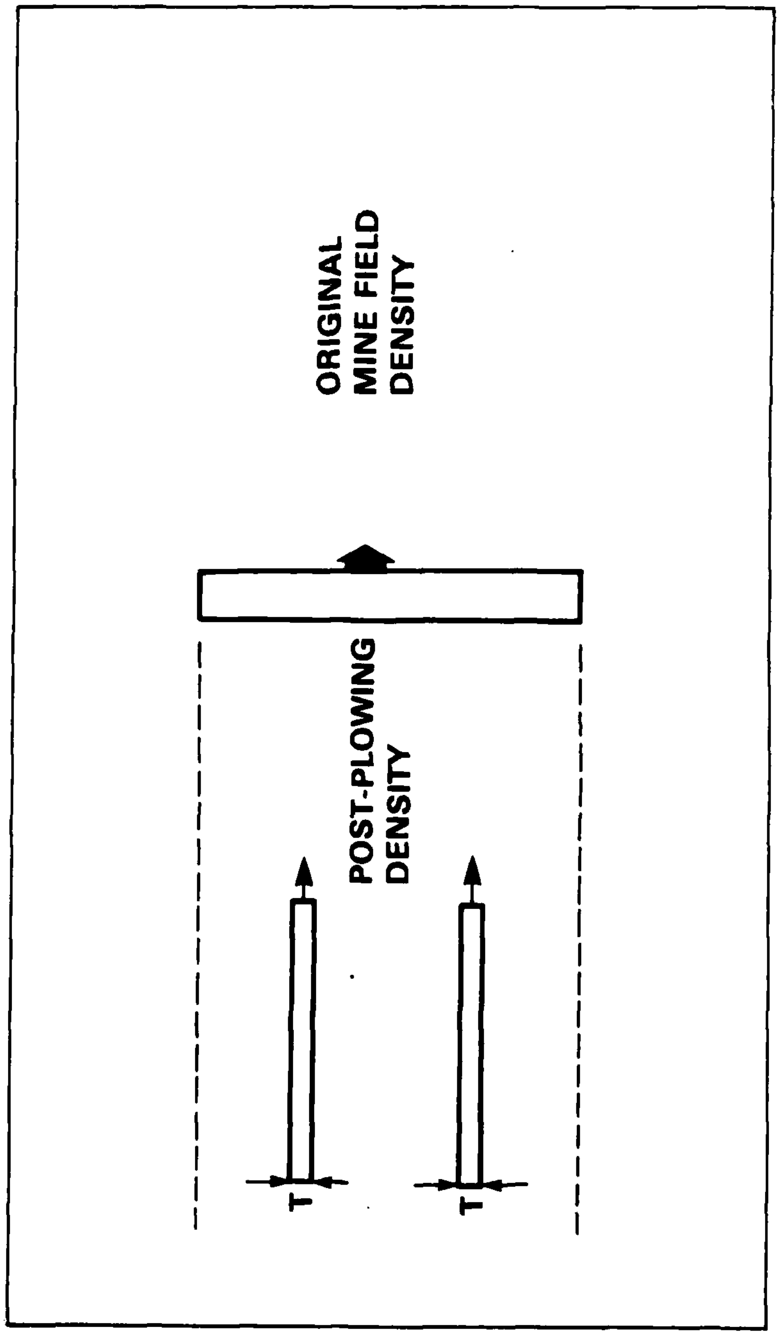


Figure III-2. Mine Plow Vehicle Passage

D. TRAILING VEHICLE SURVIVABILITY

The probability that a vehicle trailing the mine plow unit will safely traverse a cleared mine field can be computed after the mine plow and mine plow vehicle passages have been simulated. This analysis is more complex than that of the mine plow vehicle for three reasons.

The first complicating factor in this simulation is the fact that the area in front of the trailing vehicle contains three regions of different mine density, as is illustrated in Figure III-3. Region A represents that portion of the mine field which has not been traversed by the plow unit. This region has a mine density equal to the input value. Region B has been traversed by the mine plow, but not by the plow vehicle tracks. This region has a reduced mine density equal to the original density multiplied by one minus the actual plow effectiveness. Region C has been traversed by both the plow and plow vehicle tracks. This region can be assumed to have a mine density of zero, since the plow vehicle would have triggered any active mines in this region with its tracks.

Figure III-4 provides a graph of the mine density as a function of location with respect to the center of the mine plow vehicle and mechanism. The reader is referred to Figure III-3 for the definition of each region. This view, as seen from the trailing vehicle looking forward, reinforces the fact that the vehicle operator should follow the tracks of the plow vehicle. This objective becomes more and more critical as the plow effectiveness declines and the mine density in regions B correspondingly increases.

The second factor which makes this analysis complex is the fact that the trailing vehicles will not exactly follow the tracks of the plow vehicle, which is the ideal scenario. A finite deviation will exist between the intended path of the trailing vehicle and its actual path. This error can be attributed to driver navigation errors, inaccuracies in the steering system, and environmental conditions.

The amount of deviation from the target path is treated by this probabilistic simulation as having a normal distribution. Figure III-5

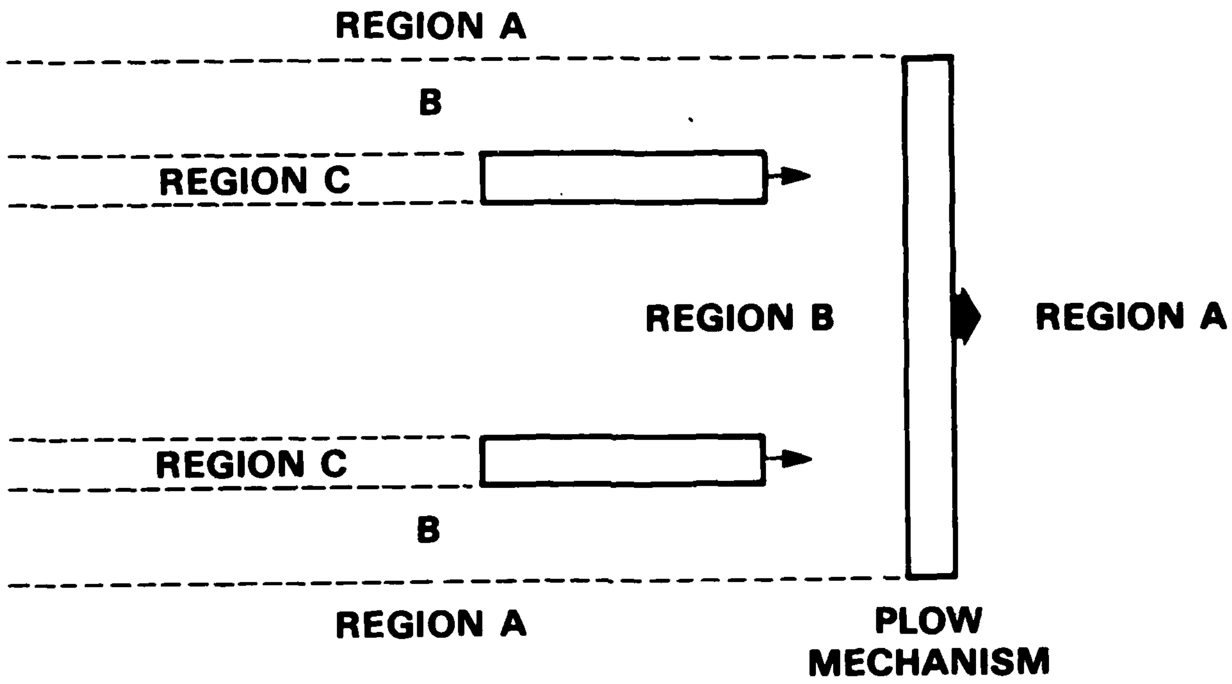


Figure III-3 Mine Density Regions Encountered by Trailing Vehicle illustrates this method. The center of the trailing vehicle is located at the middle, or peak, of the normal distribution curve. This point is the location of the vehicle for which the trailing vehicle tracks are superimposed on the tracks of the plow vehicle. Knowledge of the standard deviation for this distribution enables a determination of the probability of the trailing vehicle deviating a specified distance from its ideal path. The value for the standard deviation, presented in meters, is an input required by this module.

The probability that a trailing vehicle suffers damage or incapacitation due to an active mine is computed using several steps. First, the region within the width of the mine plow is given an average mine density. This is accomplished by computing a weighted average of the mine densities for regions B and C in Figure III-4. The result, shown in Figure III-6, is a conservative simplification of the problem. There are now only two regions of mine density in front of the trailing vehicle.

The entire spectrum of deviation from the centerline in Figure III-5 can be divided into five ranges. These ranges are defined in Figure III-7. The worst case is when both trailing vehicle tracks are in Region I, the area of highest mine density. This requires a deviation to either side of the plow width minus the overhang, D. The next case arises when one track is in Region I and the other is in both regions. Case 3 represents the instance when one track is in either region. The next case, Case 4, exists for one track being in both regions and one track being in Region II. The best scenario is Case 5, where both tracks are in the low density area of Region II.

The actual probability of a kill to a trailing vehicle is determined by summing the contributions of each case described in Figure III-7. The probability for each case is determined by the area under the normal distribution curve which corresponds to the amount of deviation from the center, defined as the X-dimension in Figure III-7. A summary of the five areas is provided in Table III-1. The W, D, and T values are also defined in Figure III-7.

The probability that a trailing vehicle will safely traverse a cleared mine field is computed as 1.0 minus the total probability of a kill.

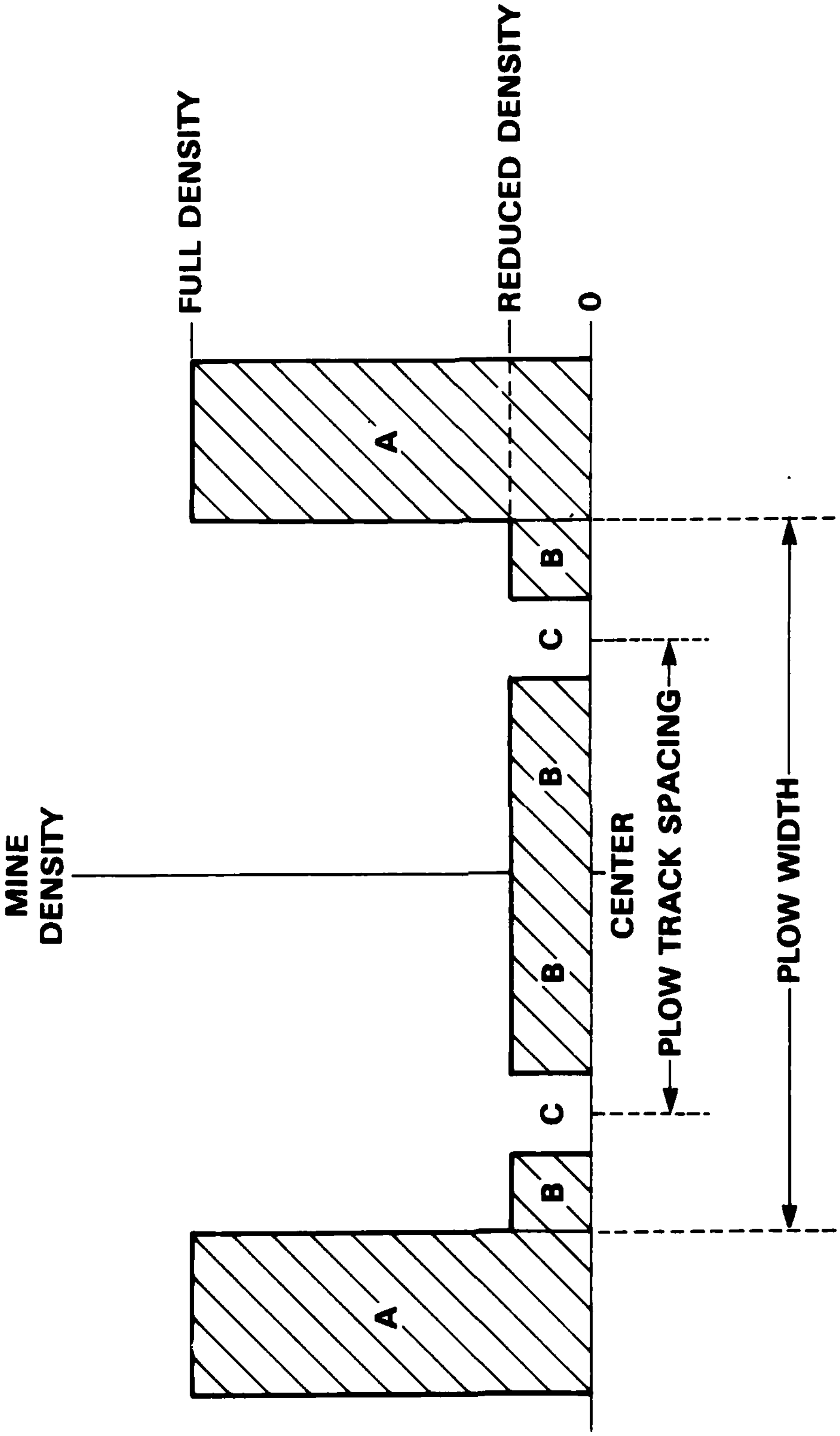


Figure III-4. Mine Density as a Function of Location

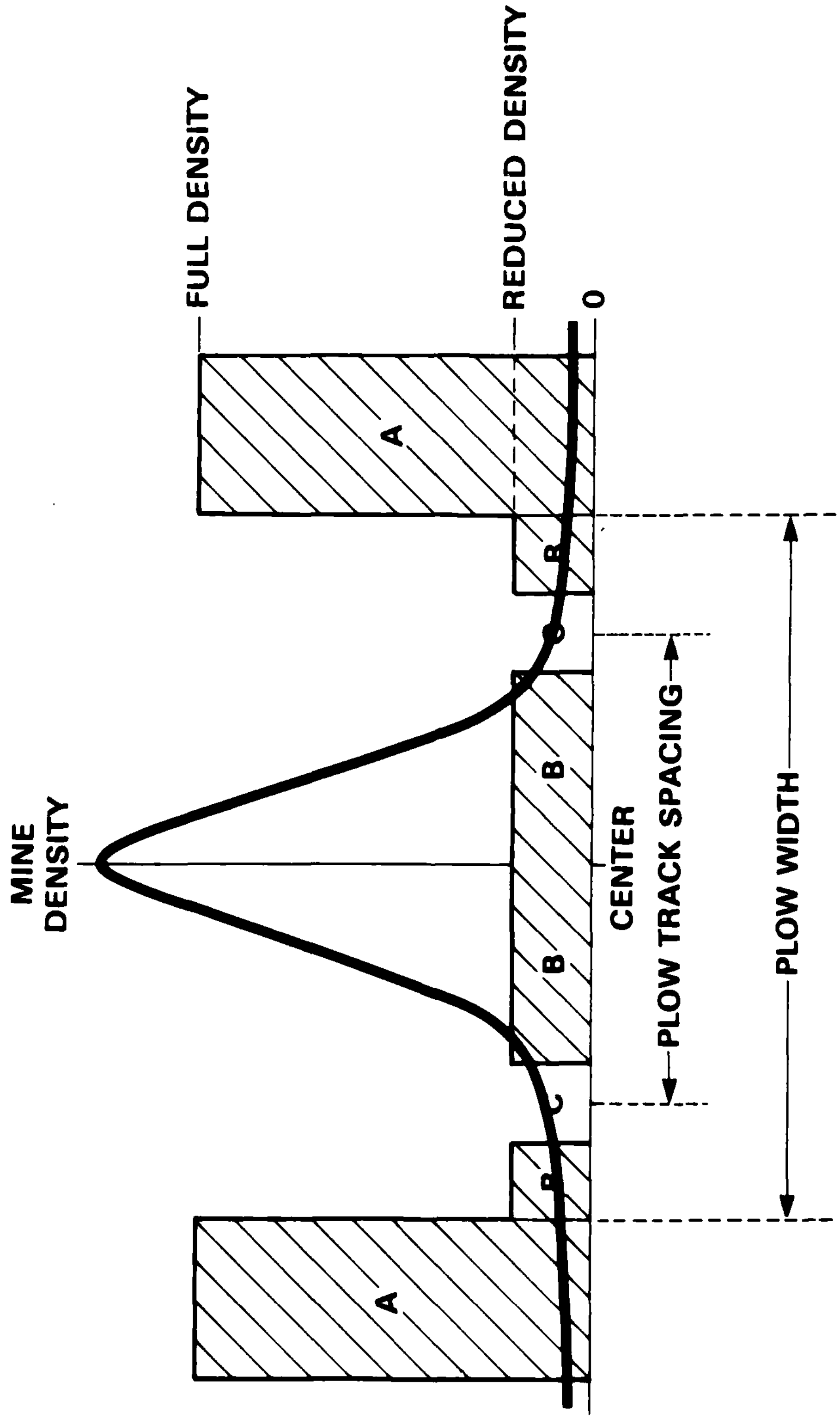


Figure III-5. Normally Distributed Navigation Error

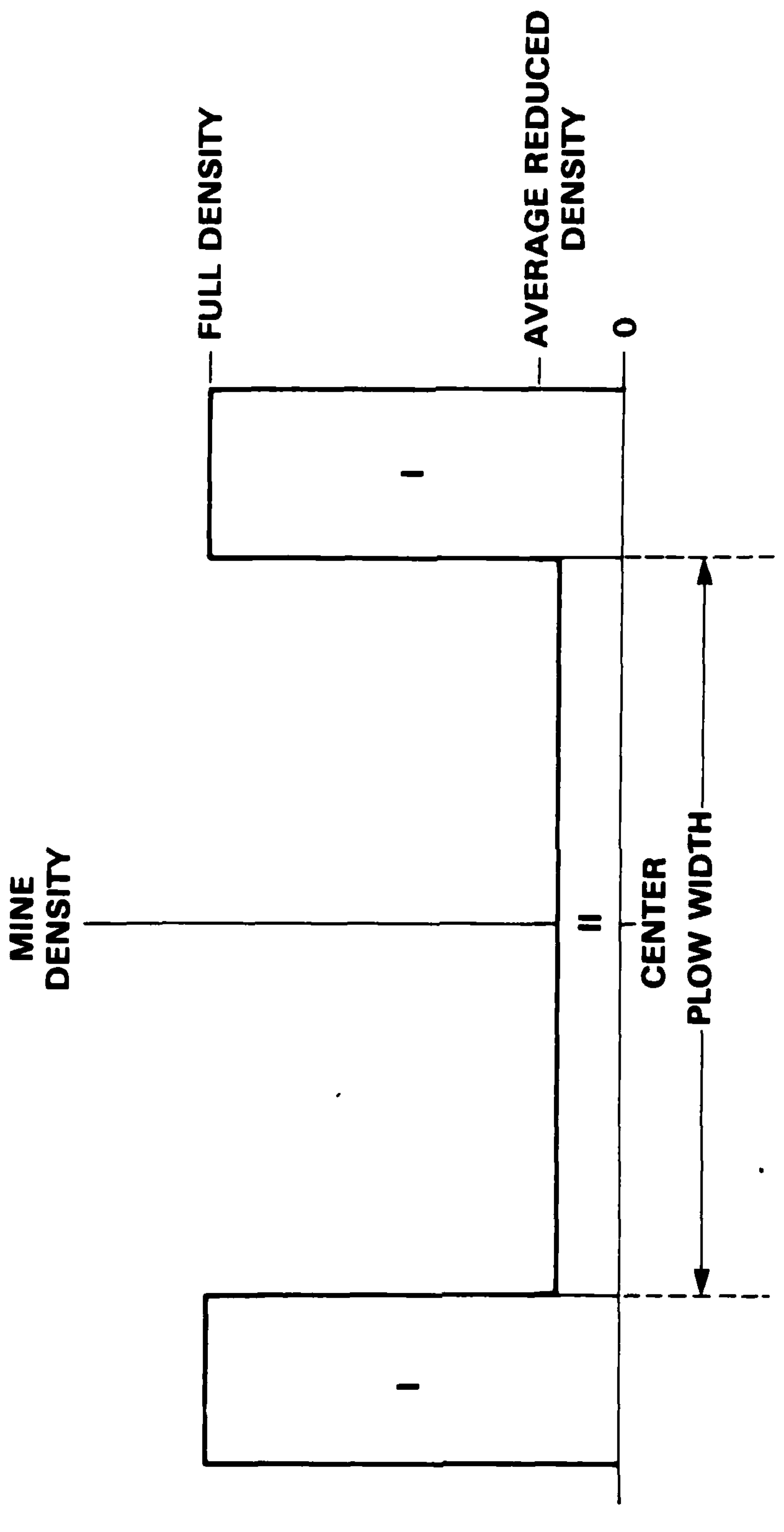


Figure III-6. Simplification of Mine Density Regions

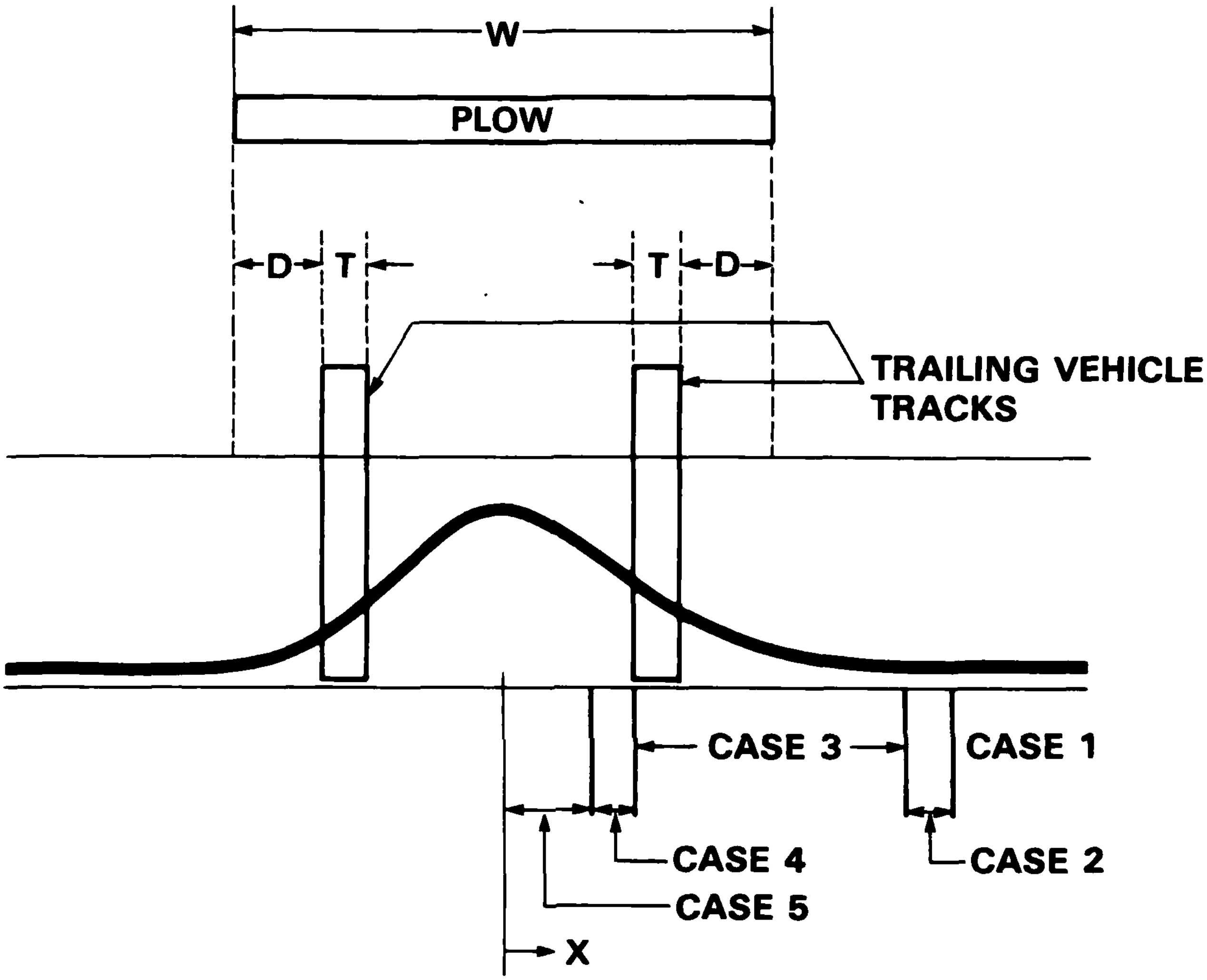


Figure III-7. Navigation Error Ranges

Table III-1. Summary of Five Regions of Deviation

REGION	X-RANGE
CASE 1	$X > (W-D)$
CASE 2	$(W-D-T) < X < (W-D)$
CASE 3	$(D+T) < X < (W-D-T)$
CASE 4	$D < X < (D+T)$
CASE 5	$0 < X < D$

E. FORMATION SURVIVABILITY

The determination of survivability for an entire formation during passage through a mine field requires three inputs. Two of the inputs, the probabilities of survival for a plow vehicle and a trailing vehicle, are intermediate values computed in separate modules of this analysis. The other input defines the total number of vehicles which trail the mine plow for a specific scenario. This is a user input in the group of values which define the scenario used for a particular analysis.

A formation passage is characterized by a traverse of the mine plow vehicle followed by the trailing vehicles. The trailing vehicles are assumed to follow the plow path in single file. This analysis treats the passage of each vehicle as an independent event. The assumption of independence is an approximation, since in reality the probability of survival for a particular vehicle increases as the number of vehicles passing ahead of it increases. For this reason, the analysis is expected to produce moderately conservative results. In order to compute the probability of a safe passage for a formation the following formula is used:

$$P_{SF} = P_{SP} \times (P_{ST})^N$$

where: P_{SF} is the probability of a safe passage for the entire formation,
P_{SP} is the probability of survival for the plow vehicle,
P_{ST} is the probability of survival for the trailing vehicle, and
N is the number of trailing vehicles in the formation.

F. DURATION OF MINE FIELD BREACH

The final module in this analysis computes the time required to breach and clear a mine field. An average time is determined as a function of plow speed, mine field length, the possibility of a mine plow vehicle casualty, and the time required to resume clearing in the event of a casualty. A breach is considered to be one sweep by the mine plow. If the desired path width is greater than the width of the mine plow, more than one pass will be required. The clearing time is computed as the breach time multiplied by the number of passes needed to cover a specified area.

The traverse of a mine field by the entire formation is computed as the clearing time added to the time required for all trailing vehicles to pass through the mine field. The traverse time is a function of clearing time, trailing vehicle velocity, mine field length, the possibility of a trailing vehicle casualty, the time penalty due to a casualty, and the total number of trailing vehicles in a formation.

CHAPTER IV

MODEL OUTPUTS

A. INTRODUCTION

This chapter describes the types of outputs which can be derived from the mine plow analysis model. It has been mentioned previously that this program was designed to be run in the Lotus 1-2-3 programming language. The presentation capabilities of this commercial software will be used to build graphs from the results of parametric analyses performed by the assessment model.

The procedures described in Chapter III produce several interesting values which should be examined during a mine plow evaluation. Four values are the results of intermediate steps. These are the probabilities of kill and survival for both a mine plow vehicle and an individual trailing vehicle. These values contribute to the determination of the final values of interest, the probability of safe passage through a mine field for a formation and the average time required to breach, clear, and traverse a mine field.

The survivability of individual vehicles and the formation is of interest for two reasons. First, the effect of various parameters on these values should be known. Relevant parameters include mine field density, plow effectiveness, and vehicle characteristics. The relation between individual vehicle survivabilities and formation survivability is also an important consideration.

The time required to defeat a mine field threat is also of interest in this analysis. The performance of a mine plow must adequately respond to time specifications in order for the unit to accomplish its mission. A minimum delay must be achieved in order to ensure continuous operations, supply, or advancement. The parameters affecting the time required to clear a mine field are mainly the plow effectiveness and speed. A trade-off will often exist between these two inputs. The time required to traverse a mine field is a function of clearing time and the number of vehicles in a formation.

This chapter will describe how an evaluation of mine plow performance can be performed with a parametric analysis technique using the parameters mentioned above as well as other critical input values. The presentation of data in graphical form using the Lotus 1-2-3 graphics features is also discussed. Chapter II provides a discussion of all required inputs to this model. Chapter III explains how these inputs are used to arrive at the final evaluation values.

B. Lotus 1-2-3 GRAPHICS CAPABILITIES

The Lotus 1-2-3 graphics feature enables the user to create informative visual representations of data generated by this mine plow assessment model. Lotus 1-2-3 is capable of transforming a table of values into an X-Y plot, a bar chart, a line chart, a stacked bar chart, or a pie chart. This function is performed with a minimum of effort on the part of the user, and can be output in color or in black-and-white. The selected graph may be embellished through the choice of various options such as chart titles, axis labels, data labels, legends, and gridding.

It is assumed here that the reader is familiar with the Lotus 1-2-3 commercial software package. The Lotus 1-2-3 User's Manual provides a good description of the software features and how they can be used to enter, create, and manipulate information. This manual is recommended for use by users of this analysis methodology.

C. GRAPHICAL OUTPUTS FROM THE MINE PLOW ASSESSMENT MODEL

1. Introduction

This section will describe the generation of graphical outputs from the mine plow assessment model. The information which will be presented in chart form, as has been mentioned earlier, consists of probabilities of survival and average clearing times for a specified formation. The input parameters which will drive these values include mine field density, plow effectiveness, vehicle characteristics, plow speed, and mine field length.

The following paragraphs describe how a table is set up in a Lotus 1-2-3 worksheet to provide the X and Y data used to create a chart. The final part of this section defines several useful parametric analyses to be performed and provides examples of graphical output created in the Lotus 1-2-3 system by the assessment model.

2. Creation of Data Table Using Parametric Analysis

The mine plow evaluation model as it is physically designed occupies one row of a Lotus 1-2-3 worksheet. The program inputs are located at the front in the first third of the model. Computations and intermediate values are found in the middle columns and near the end of the row. The final few columns contain the overall results of the mine plow evaluation model.

In order to generate a table from which charts can be produced a parametric study must be performed. The single row as described in the preceding paragraph may be copied exactly into another row using one of the simple Lotus 1-2-3 commands. A row may be copied as often as is desired to produce a set of rows, each of which represents the entire plow assessment model.

The result of copying a row several, or many, times is a table in which each row is identical to the other rows. At this point, a parametric analysis may be performed. The user may now move from row to row in a particular column and change the values for the input parameter contained in that column. As the value is changed, the program in that row will recompute all intermediate and final values to accomodate the new parameter choice. All other inputs should remain constant in order to isolate the effects of a single parameter. The parameter should be altered in a natural numerical progression from top to bottom within the table in order to produce a meaningful plot.

After the parametric analysis has been completed, the results may be converted into graphical output. The user must designate the column containing the parameter which was varied as the "X" data, and the column containing the result of interest as data to be plotted on the y-axis of the graph. Lotus 1-2-3 supports the inclusion of up to six different graphs for a single group of x-axis points. The result will be a plot showing the effect of an input parameter on mine plow performance results. This is an extremely effective method of presenting valuable information.

The generation of a separate parametric evaluation is very simple to perform using the Lotus 1-2-3 package. The user must only move between rows and columns to change values in any desired location. Values in the column containing the last parameter studied must all be changed to a single value. Values for a different input parameter may then be varied. As the values are changed, the results in the respective rows will change accordingly. After the entire table has been completed, a new graph can be produced.

3. Suggested Parametric Evaluations

The most critical input parameters to the evaluation model are the mine field length, mine field density, plow speed, plow efficiency, and desired path width. The model results of interest are the plow vehicle survivability, trailing vehicle survivability, formation survivability, and mine field clearing time. The most interesting analyses are expected to emerge from studies involving these two groups of information.

Figure IV-1 presents a graph of the probability of survival for a formation as a function of mine field density. A chart of this type may be used to predict the performance of a specified mine plow mechanism against a varying level of threat. In this way, any limits on the usage of a certain system in expected threat environments may be determined. It should be noted here that all data shown in this and the following figures is hypothetical and should not be construed as accurate or reliable.

FORMATION SURVIVABILITY VS. MINE FIELD DENSITY

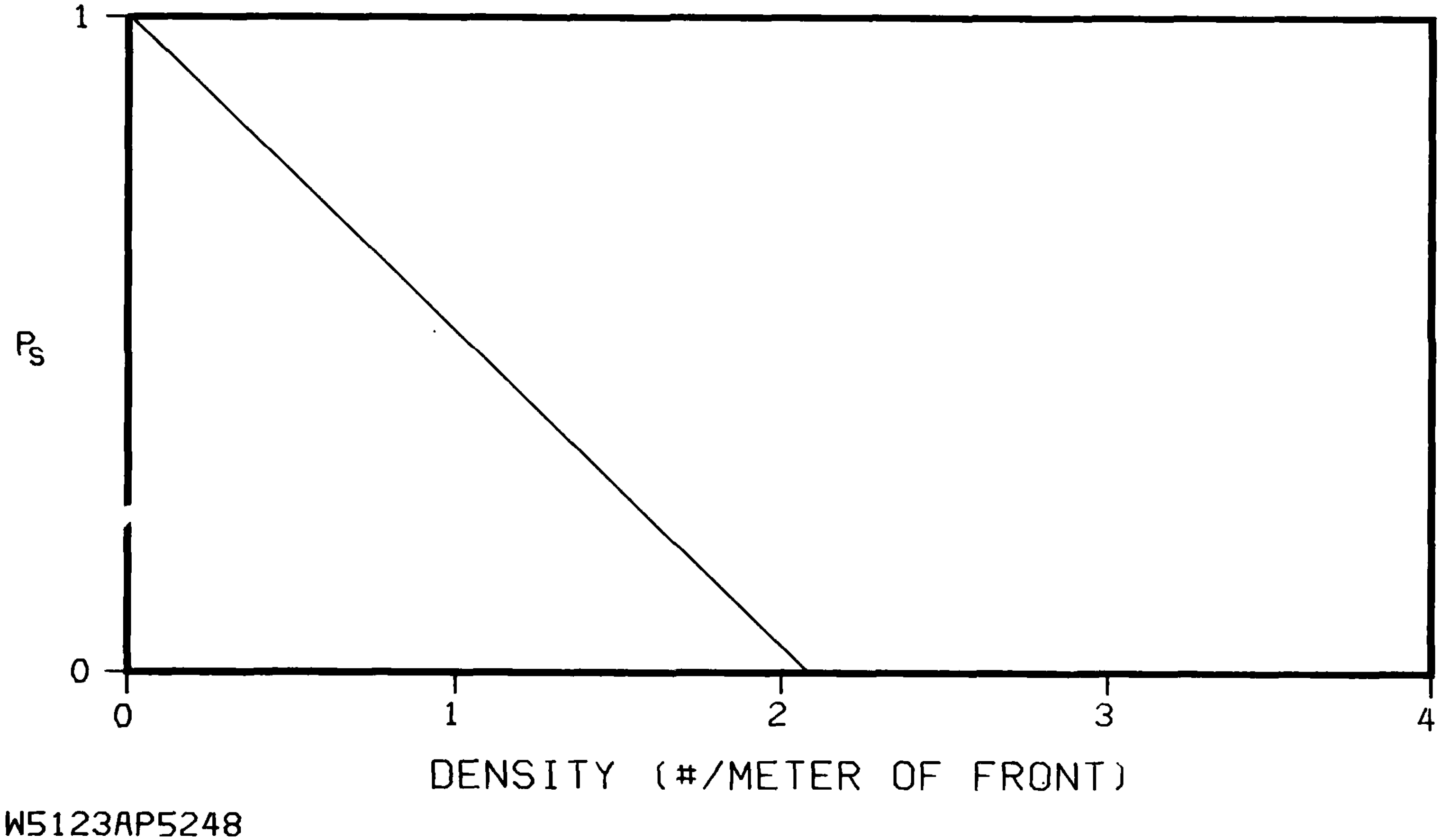
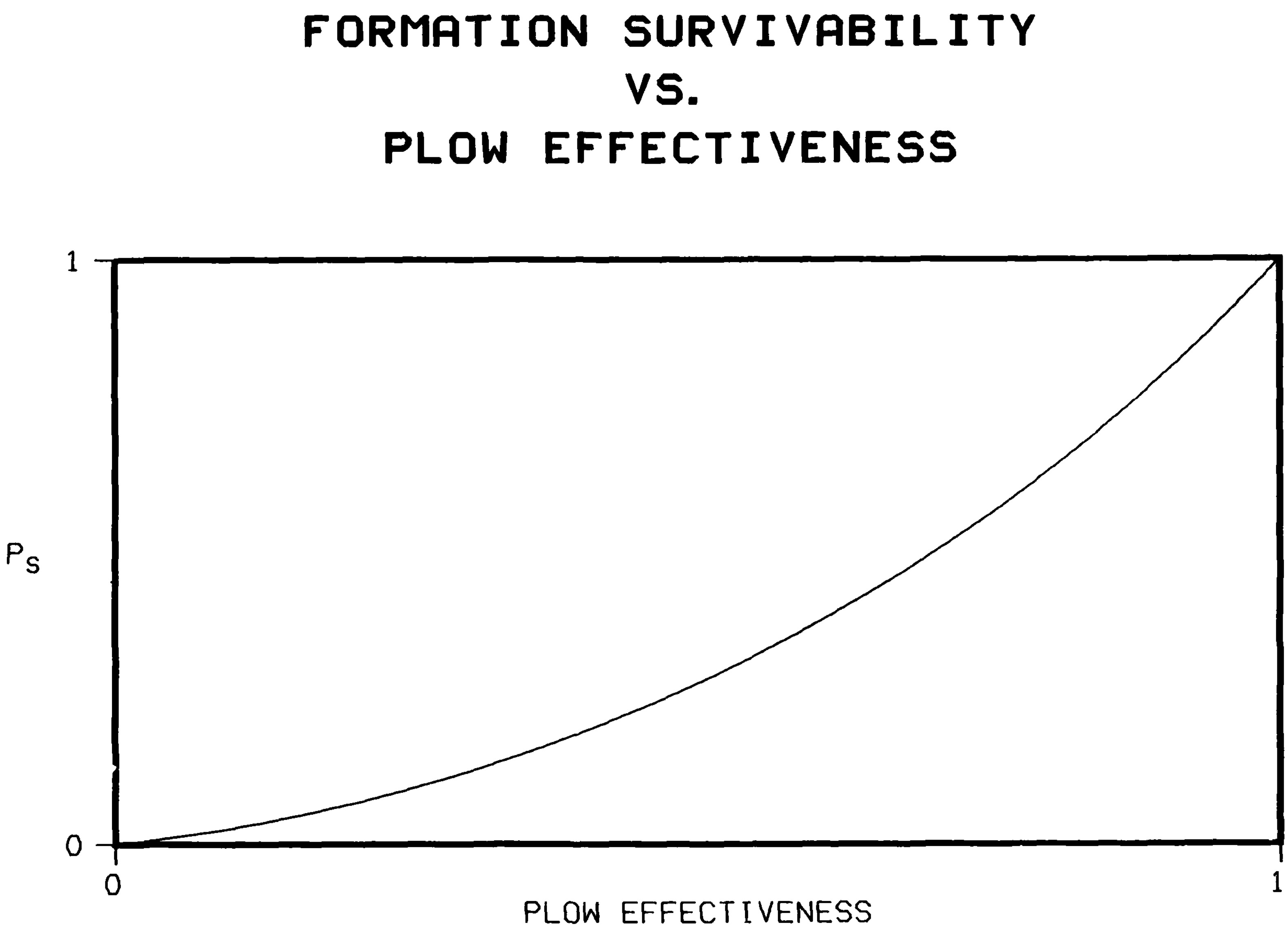


Figure IV-1. Formation Survivability vs. Mine Density

Figure IV-2 illustrates the dependence of formation survivability on plow mechanism effectiveness. This plot can be very useful in determining the characteristics of a specific mine plow mechanism. The user is able to quickly determine the minimum plow effectiveness required to provide the formation with a specific probability of safe passage. Similar results for the trailing vehicle probability of survival are plotted in Figures IV-3 and IV-4. A possible alternative would be to use the probability of kill in place of probability of survival. This would communicate the same information to a reader of the charts.

Figure IV-5 shows the clearing time as a function of plow effectiveness. This inverse dependence is caused by the fact that there will be fewer casualties as the plow effectiveness increases.



W5123A05248

Figure IV-2. Formation Survivability vs. Plow Effectiveness

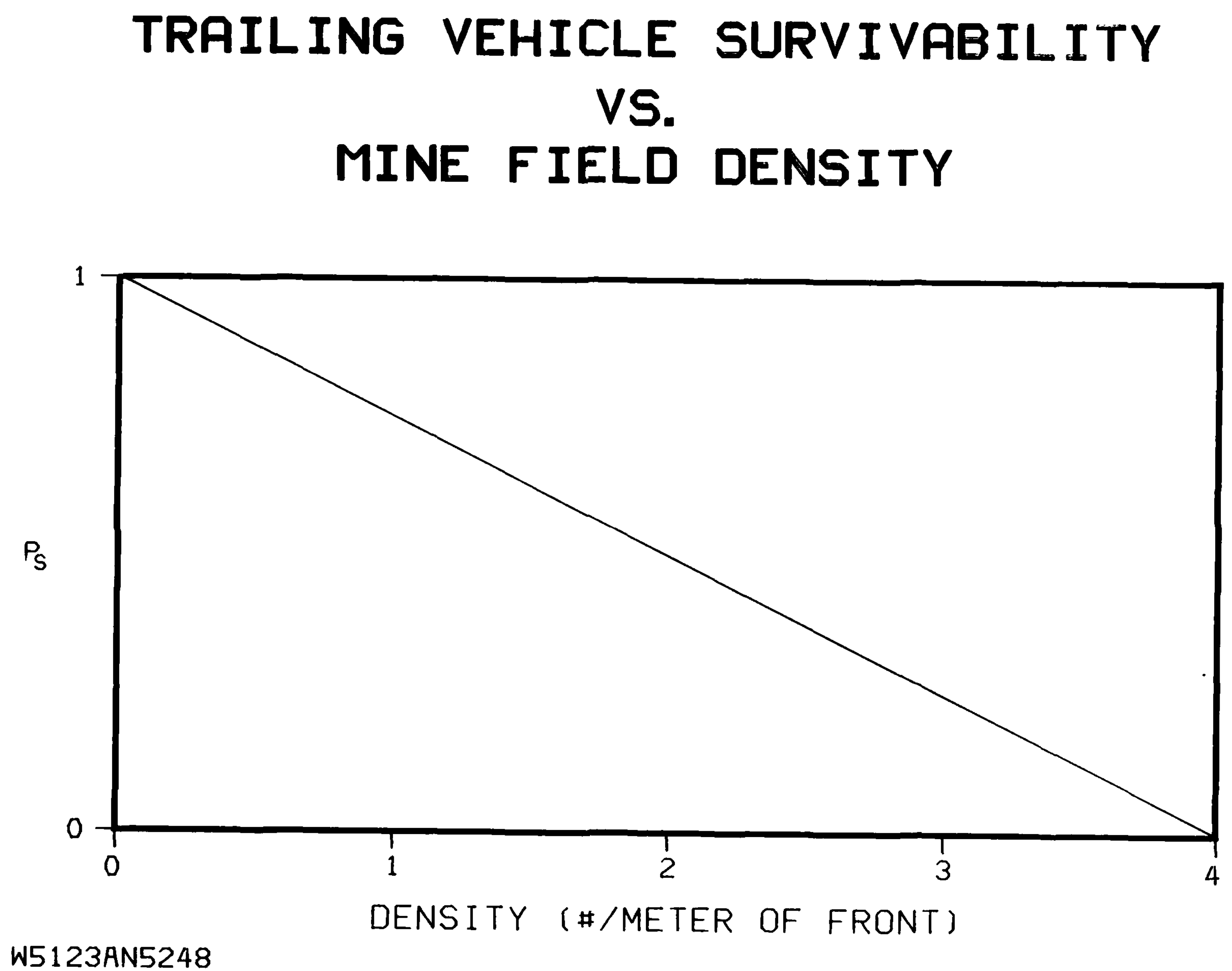


Figure IV-3. Trailing Vehicle Survivability vs. Mine Density

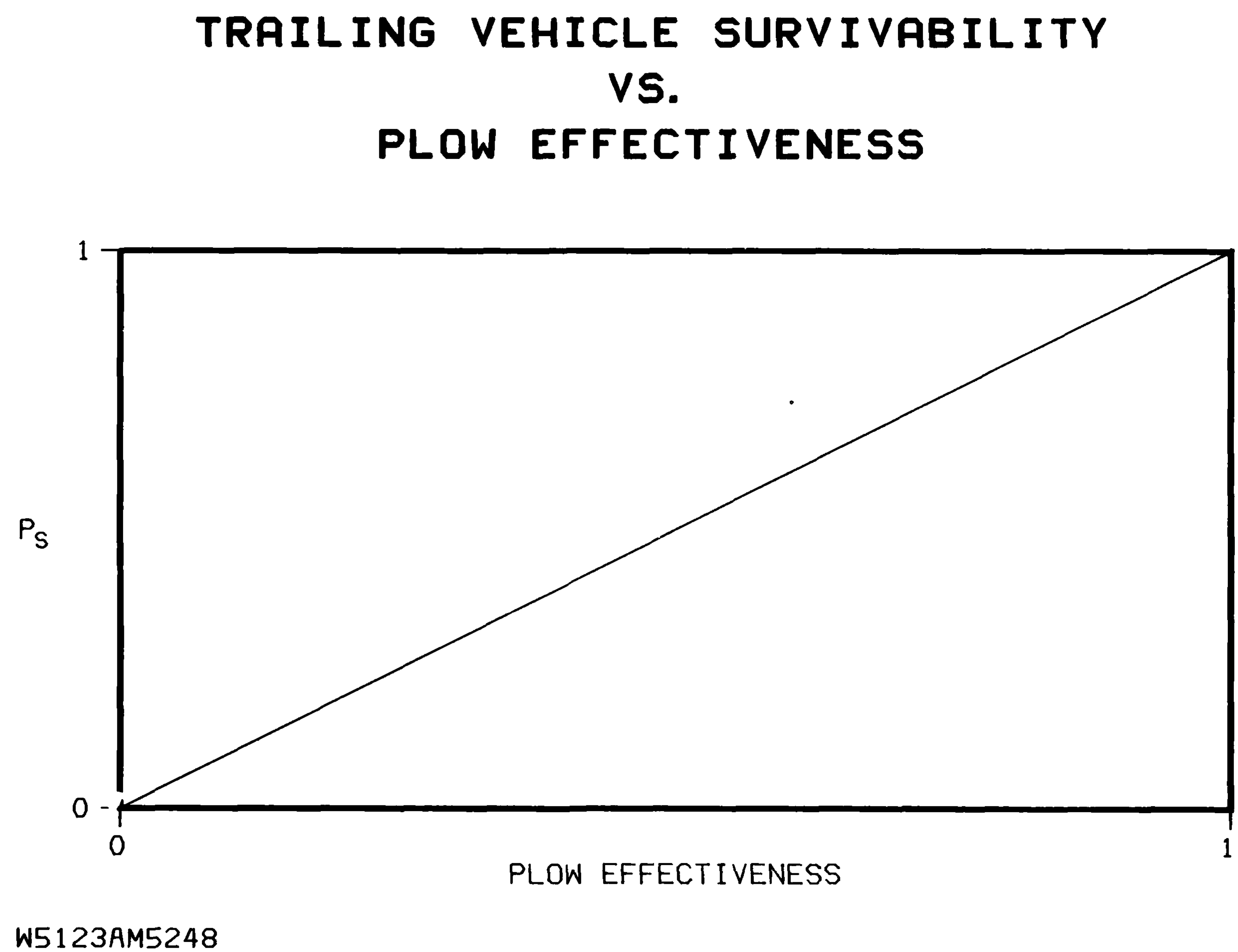


Figure IV-4. Trailing Vehicle Survivability vs. Plow Effectiveness

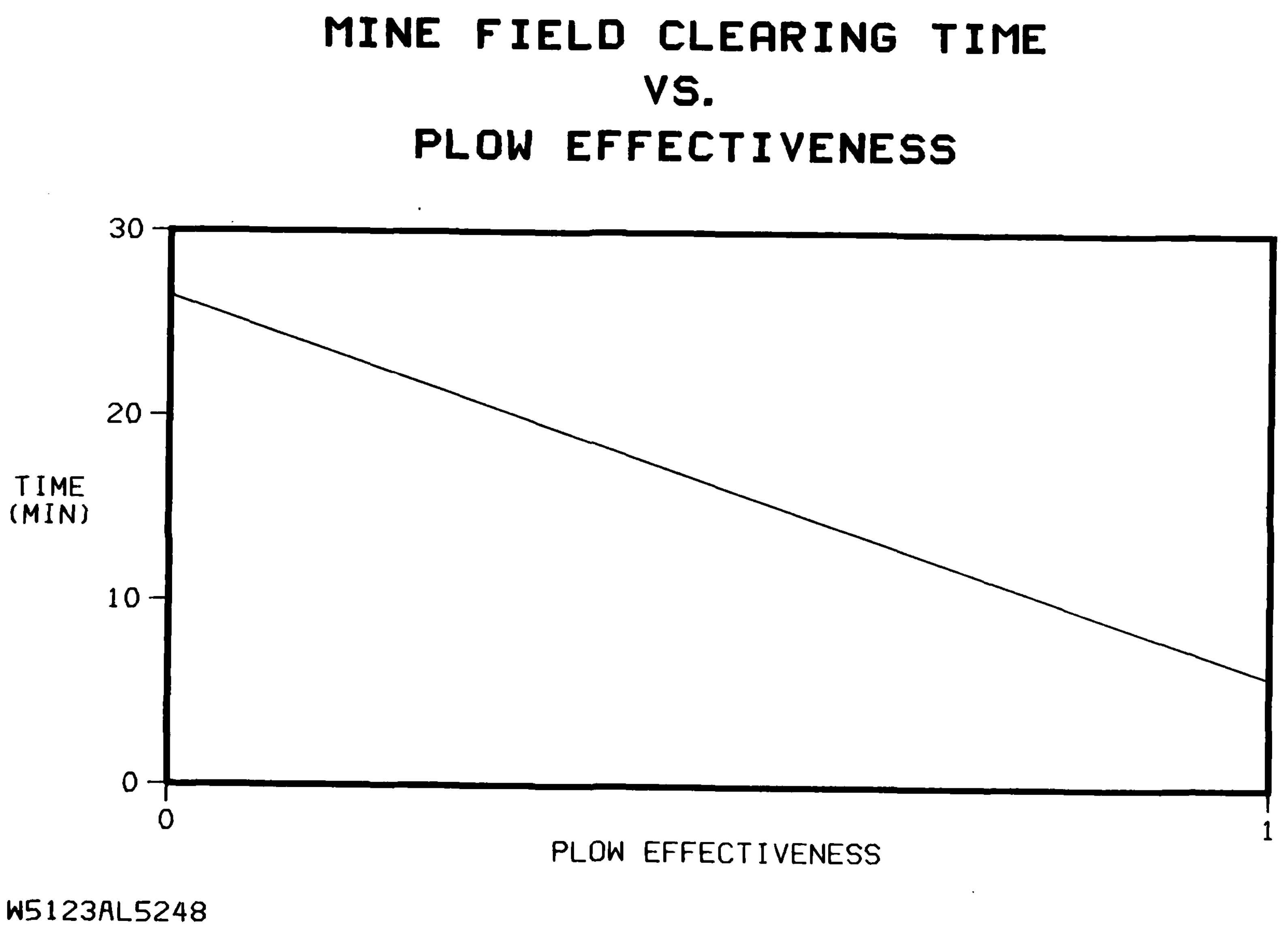


Figure IV-5. Clearing Time vs. Plow Effectiveness

CHAPTER V

USING THE MINE PLOW ASSESSMENT MODEL

A. INTRODUCTION

The purpose of this chapter is to provide the reader with a better understanding of the evaluation model. This will be accomplished by leading the user through a hypothetical simulation of mine plow performance. The inputs used and results obtained in this simulation should not be considered valid or reliable. The values seen in this chapter exist solely for the sake of example.

The next two sections of this chapter will briefly describe the hardware and software used to access and operate the mine plow evaluation model. The final two sections are devoted to the illustration of an example evaluation. Inputs and outputs are presented.

B. SYSTEM HARDWARE

1. Introduction

The mine plow evaluation methodology has been designed to operate on the IBM series of personal computers. It has been tested and found to be fully operational on the IBM-PC, IBM-XT, and IBM-AT systems. The IBM computers are powerful units capable of handling complex computational demands as well as detailed graphics requirements. This system was chosen due to these capabilities in addition to its low cost and high availability. All the capabilities of the unit are available to the user when the user wishes to access them. The delays common among large mainframe computer systems, such as heavy usage or communications difficulties, do not exist with the personal computer. The drawbacks of the personal computer are that it has limited storage capabilities and that it runs slower than the larger computers. These disadvantages, however, are not significant for the applications required by this evaluation model.

The Engineer Support Laboratory has an IBM-PC personal computer, which is presently located in the Program Office. The evaluation model has been operated on this particular system and, if a different system must be used or obtained, it is suggested that the same architecture be made available. This section will describe the hardware features of the IBM-PC.

2. IBM-PC Hardware

Figure V-1 shows the present hardware configuration for the IBM-PC workstation located in the Program Office. Each of the elements is described below:

a. Processing Unit

The processing unit contains the electronic circuitry of the IBM-PC, including floppy drives, boards, modem, and random access memory (RAM). The hardware units outside of the processing unit are either input (floppy drive and keyboard) or output (monitors, printer, and plotter) devices which communicate with the processor through cables.

b. Floppy Drives

The IBM-PC contains two floppy disk drives. The left hand, or "A" drive is the default drive, and is generally used for loading software and initializing the system. The right hand, or "B" drive is generally used for loading data which will be manipulated by the software. These drives accept the standard 5 1/4" inch diskette.

c. Color Monitor

This is the main monitor for the system. It is a Princeton Graphics monitor, and is driven by a color graphics board which has been installed inside the computer processing unit.

d. Monochrome Monitor

This is the standard IBM monochrome monitor, which is used in this system as the secondary unit.

e. Color Plotter

The Hewlett-Packard 6-pen color plotter is used to generate quality graphics for either paper or transparencies. The unit is driven by a variety of software packages, including Lotus 1-2-3 and PFS:Graph.

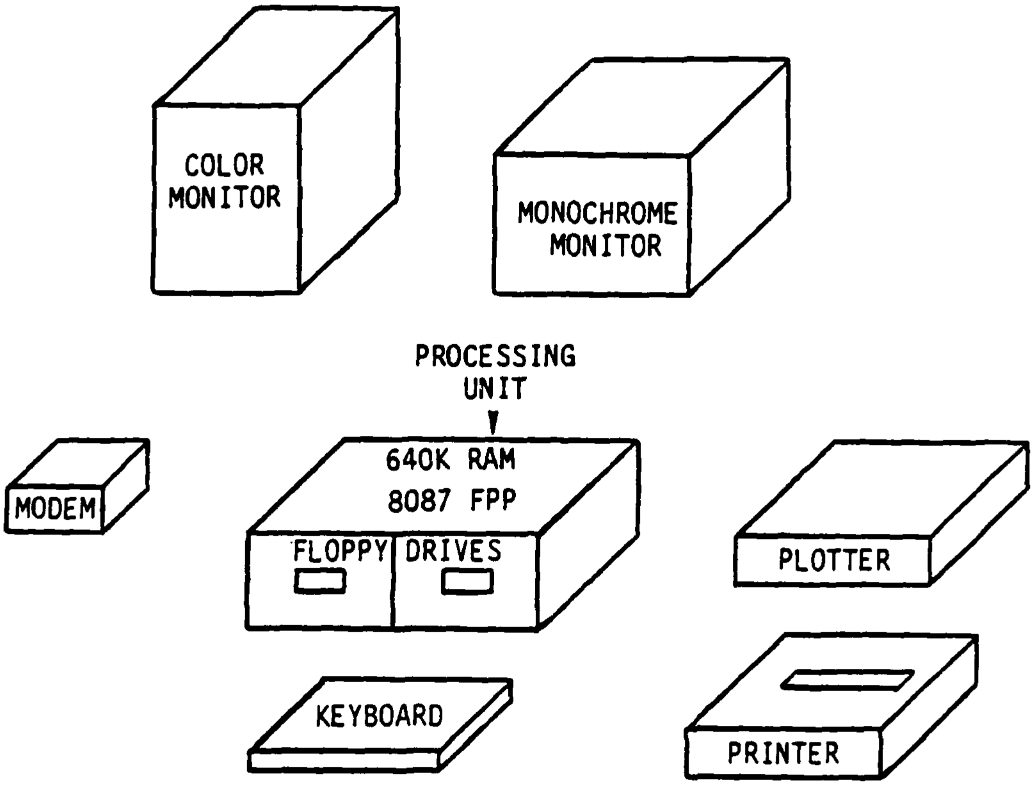


Figure V-1. IBM-PC Workstation

f. Printer

The Epsom printer is used to print output from the various software packages, including the PFS series, LOTUS 1-2-3, and the Volkswriter word processor.

g. Keyboard

The standard IBM keyboard is used for entering all user commands.

h. Modem

This system contains an internal Hayes modem, which can be used to communicate with other personal computers or to act as a terminal to the central computers. The unit is driven by a board located in the processing unit and is controlled by either the CROSSTALK or Hayes SMARTCOM II communications software packages.

i. Math Processor

An Intel 8087 floating point processor has been installed within the processor unit to increase the speed of the personal computer when performing mathematical operations.

j. RAM

This IBM-PC has been provided with the maximum amount of RAM, or random access memory.

C. SYSTEM SOFTWARE

1. Introduction

Operation of this simulation model requires the use of two commercial software packages. The first package is the operating system for the IBM-PC computer. The next part of this section will describe how this software is used. The other software package required is Lotus 1-2-3. The rest of this section illustrates the use of Lotus 1-2-3 for this application.

Lotus 1-2-3 was chosen as the driver for the mine plow evaluation model for three main reasons. First, this package possesses rapid computational capabilities which allow timely use of the simulation model.

Secondly, the spread sheet format used when programming in Lotus 1-2-3 provides an appealing method of viewing the model in operation and scanning results. Finally, the results of several program runs, as in a parametric analysis for example, can be presented effectively, quickly, and easily in graphical form using Lotus 1-2-3.

2. <u>Using the IBM-PC Disk Operating System (DOS)</u>

a. <u>Getting Started</u>

In order to use the personal computer, the operating system must first be installed on the machine.

- Place the DOS diskette in the "A" drive of the computer (left drive).
- Turn on machine, monitor, and printer.
- After reading files from the diskette and running a self-check, the computer will prompt "CURRENT DATE IS TUE 1-01-1980 ENTER NEW DATE:"
  - Type: CORRECT DATE <CR> <u>or</u>
  - Type: <CR>
- Computer will prompt "CURRENT TIME IS 0:00.XX.XX ENTER NEW TIME:"
  - Type: CORRECT TIME <CR> <u>or</u>
  - Type: <CR>
- Computer responds with a message and the prompt for the default drive: "A> ".
  - The user is now able to perform operations through the IBM-PC operating system.

b. <u>Frequently Used Commands</u>

1) <u>COPY</u>

This copies one or more files to another disk or to the same disk with a different name. If no disk drive is specified, the default is assumed.

Example: COPY A:FILE1 B: <CR> copies the file named FILE1 from a diskette in the "A" drive (left) to a diskette in the "B" drive (right).

Example: COPY A:FILE1 A:FILE2 <CR> copies the file named FILE1 onto the same diskette but with the new name FILE2.

2) DELETE

This command deletes a file or group of files from the specified disk.

Example: DEL A:FILE1 <CR>

3) Directory Listing

This command produces a listing of a file or group of files on the specified or default disk.

Example: DIR <CR> produces a listing of all the files on the default drive diskette.

Example: DIR B: *.Z <CR> produces a listing of all files on the "B" drive diskette which have an ending of "Z".

4) Format

Before information can be stored on a diskette, it must be initialized.

Example: FORMAT A: <CR> will format the diskette in drive "A".

NOTE: This process will destroy all information presently on the diskette.

5) Changing Default Drive

To change the default drive, merely type the desired drive letter followed by a colon and press <CR> .

Example: At the "A>" prompt

Typing B: <CR> will change the default drive from "A" to "B" and the new prompt will be "B>".

3. Lotus 1-2-3 Spread Sheet Programming

The spread sheet feature provided by Lotus 1-2-3 allows the user great flexibility in designing the structure of a program. The mine plow assessment model was designed to occupy one row of a Lotus 1-2-3 worksheet. Due to the large number of steps used in making the necessary computations, the model is too large to be viewed on the screen at one time. This makes working with the program tedious, since the inputs are at the front of the row and the results of interest are many columns to the right at the end of the row. To bypass this inconvenience, the model makes use of the Lotus 1-2-3 feature known as windowing. This allows the user to split the screen into two independent screens. In this way the user may make changes in the input section of the program and observe the changing results in the other screen.

Figure V-2 presents the mine plow evaluation model as it would appear on the monitor. Note the use of windowing as described in the previous paragraph. Figure V-3 shows the monitor screen after the model has been copied into several rows. In this particular example, the input value for mine field density has been varied while the other values remain constant from row to row. This is an example of how a parametric analysis can be performed using the mine plow model and Lotus 1-2-3. Note the corresponding changes in the results on the right half of the screen. Those results may be plotted as a function of mine density using the LOTUS 123 graphics feature or they may be printed as a table.

4. Operating the Mine Plow Model Using Lotus 1-2-3

a. Getting Started

- Make sure that the computer has been turned "ON" and that the disk operating system has been loaded (see Section 2).
- Place the Lotus 1-2-3 System Disk in the "A" drive of the computer (left side).
- Place the diskette containing the mine plow evaluation model in the "B" drive of the computer (right side).
- At the "A>" prompt,

  Type: Lotus<CR>

```
        A            B          C          D          E          CF          CG          CH
1                 MINE       MINE       MINE              1                 AVG         AVG
2                FIELD      FIELD      FIELD              2       PROB    BREACH       CLEAR
3               LENGTH      WIDTH    DENSITY              3        ALL      TIME        TIME
4                  (M)        (M)      (#/M)              4       PASS     (MIN)       (MIN)
5     ------------------------------------------------------5   ------------------------------
6                  100         50          3              6   0.006089  12.55555    25.11111
7                                                         7
8                                                         8
9                                                         9
10                                                        10
11                                                        11
12                                                        12
13                                                        13
14                                                        14
15                                                        15
16                                                        16
17                                                        17
18                                                        18
19                                                        19
20                                                        20
```

Figure V-2. View of Analysis Methodology Using LOTUS 123 Window Feature

	A	B	C	D	E		CF	CG	CH
1		MINE	MINE	MINE		1		AVG	AVG
2		FIELD	FIELD	FIELD		2	PROB	BREACH	CLEAR
3		LENGTH	WIDTH	DENSITY		3	ALL	TIME	TIME
4		(M)	(M)	(#/M)		4	PASS	(MIN)	(MIN)
5						5			
6		100	50	0		6	1	0.555555	1.111111
7		100	50	0.5		7	0.521476	2.555555	5.111111
8		100	50	1		8	0.256461	4.555555	9.111111
9		100	50	1.5		9	0.117546	6.555555	13.11111
10		100	50	2		10	0.049412	8.555555	17.11111
11		100	50	2.5		11	0.018626	10.55555	21.11111
12		100	50	3		12	0.006089	12.55555	25.11111
13						13			
14						14			
15						15			
16						16			
17						17			
18						18			
19						19			
20						20			

Figure V-3. Formation of Parametric Analysis Table

- Computer responds with the Access System Menu. To make a selection from the menu either move the cursor to your choice and press CR, or type the first letter of your choice.
- Select the first choice (1-2-3) by pressing <CR> or

  Type: 1
- Computer responds with message and a prompt to press any key in order to continue
- Press a key
- Computer displays a blank worksheet with the cursor at the upper left corner. The user may now create a spreadsheet or call up a previously stored worksheet for viewing or alterations.

b. Using the Plow Model

- Press the BACKSPACE key at lower right to enter the COMMAND MODE.
- Computer will display the Main Command Menu at the top of the screen. The cursor will be on the first choice.
- Select the FILE Command by typing "F" or moving the cursor to FILE and pressing <CR> .
- Computer will display the available file commands.
- Select the RETRIEVE Command.
- Computer displays the files stored on the diskette in drive "B".
- Select the file you wish to work on by moving the cursor to it and pressing <CR> or by typing the file name and pressing <CR> . The mine plow model is named "MINEPLOW".
- Computer will display the selected worksheet with the cursor located at the cell it occupied when the file was saved.
- Move the cursor to the area which requires changes, additions, or deletions and perform the desired operations.
- When you have finished working on the file, remember the SAVE it before moving on, or all your new work will be lost.
- Press the BACKSPACE key
- Select the FILE Command
- Select the SAVE Command

- Computer responds with a list of previously stored files and places the cursor at the first file.
- If you wish to SAVE the original file, type in a new name for the updated file and press <CR> .
- If you wish to REPLACE the original file with the new file, select the name of the original file and press <CR> .
- The computer will ask if the user wishes to REPLACE the already existing file or CANCEL the command.
  - Type: R or move the cursor to REPLACE and press <CR> .

c. Existing Lotus 1-2-3

- SAVE your most recent work if you do not want to lose it.
- Press the BACKSPACE Key to access the Main Command Menu.
- Select the QUIT COMMAND.
- Computer will ask you if you wish to QUIT this Lotus 1-2-3 session.
- Select "YES".
- Computer returns to the Access System Menu.
- Select EXIT.
- Computer will ask you if you wish to EXIT the Lotus 1-2-3 System.
- Select "YES".
- Computer returns to its operating system and prompts with "A>".

D. INPUTS FOR SAMPLE MINE PLOW ANALYSIS

1. Introduction

This section presents an example set of inputs to the mine plow assessment model. These inputs were used in a hypothetical analysis in order to acquaint the reader with the system. Results of parametric analyses are presented in the next section of this chapter.

2. Inputs

Parameter	Value
Mine Field Length	100 m
Mine Field Width	50 m
Mine Field Density	1 mine per meter of front
Mine Radius	0.1 m
Mine Height	0.15 m
Mine Depth	0.2 m
Mine Detonation Probability	1.0 m
Plow Width	4.0 m
Plow Depth	0.25 m
Plow Speed	3 mps
Plow Efficiency	0.8
Plow Track Width	0.5 m
Plow Track Spacing	2.0 m
Plow Overhang	0.5 m
Trailing Vehicle Track Width	0.5 m
Trailing Vehicle Track Spacing	2.0 m
Trailing Vehicle Plow Overhang	0.5 m
Path Width	5.0 m
Number of Following Vehicles	7
Navigation Standard Deviation	0.20 m
Casualty Time Penalty	20 min

E. MODEL OUTPUTS

1. Introduction

This section presents the results of parametric analyses conducted using the mine plow evaluation model. The inputs defined in the previous section of this chapter were used, and several of the parameters were examined to determine their effect on the results.

The parameters varied for the purposes of this example were the mine field density, mine plow mechanism effectiveness, and trailing vehicle navigation error. The remainder of this chapter discusses the results of these parametric analyses.

2. Mine Field Density Analysis

Figure V-4 presents the table developed within Lotus 1-2-3 in order to determine the effect of mine field density on the mine plow performance results. Note the changes in the results on the right-hand screen as a function of the mine field density which was varied on the left-hand screen. These relationships are represented graphically in Figures V-5 and V-6. Figure V-5 illustrates the effect of mine density on the probability that an entire formation will safely pass through a minefield. The sharp decline in performance may limit deployment of this system. Figure V-6 shows that the average time required to clear a path through a mine field will increase as the mine density increases. This relationship is important, especially in tactical situations.

3. Plow Effectiveness Analysis

Figure V-7 presents the results of a parametric analysis involving the plow effectivness. These results have been presented in tabular form as they would appear on the monitor. Figure V-8 illustrates the significant dependence of plow performance on the plow mechanism effectiveness. These results state that a high effectiveness must be obtained in order to allow safe passage. Figure V-9 shows the inverse relation between plow effectiveness and the average mine field breaching time.

4. Trailing Vehicle Navigation Error Analysis

The results of this parametric analysis are shown in Figure V-10. The only result shown which is affected by this input is the probability that the entire formation will safely traverse the mine field. This relationship, presented in Figure V-11, shows that the dependence of the results on this parameter is not as strong as for the other parameters examined in this example.

	A	B	C	D	E		CF	CG	CH
1		MINE	MINE	MINE		1		AVG	AVG
2		FIELD	FIELD	FIELD		2	PROB	BREACH	CLEAR
3		LENGTH	WIDTH	DENSITY		3	ALL	TIME	TIME
4		(M)	(M)	(#/M)		4	PASS	(MIN)	(MIN)
5						5			
6		100	50	0		6	1	0.555555	1.111111
7		100	50	0.25		7	0.723509	1.555555	3.111111
8		100	50	0.5		8	0.516291	2.555555	5.111111
9		100	50	0.75		9	0.362918	3.555555	7.111111
10		100	50	1		10	0.250939	4.555555	9.111111
11		100	50	1.25		11	0.170394	5.555555	11.11111
12		100	50	1.5		12	0.113407	6.555555	13.11111
13						13			
14						14			
15						15			
16						16			
17						17			
18						18			
19						19			
20						20			

Figure V-4. Mine Field Density Parametric Analysis

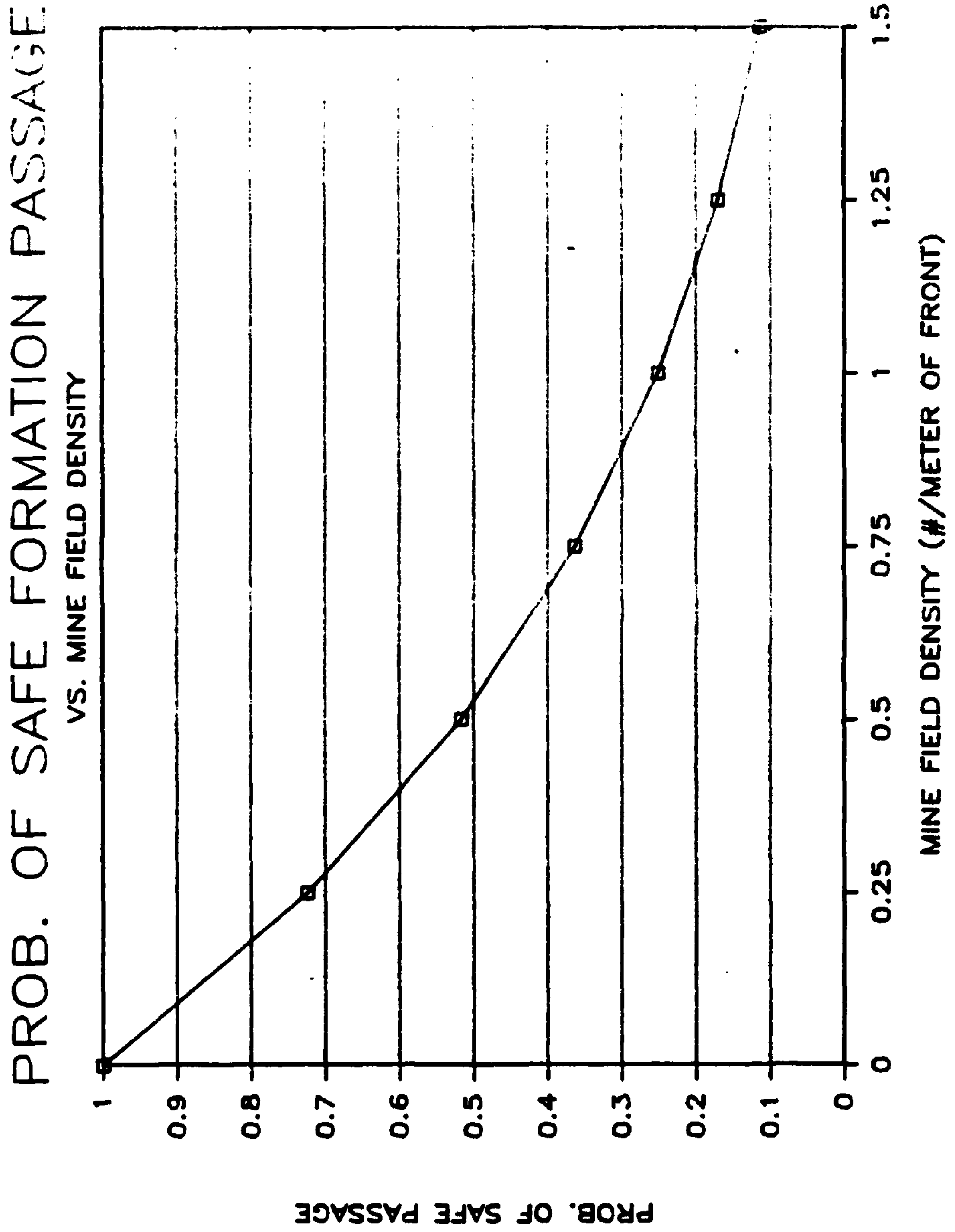


Figure V-5. Formation Survivability vs. Mine Field Density

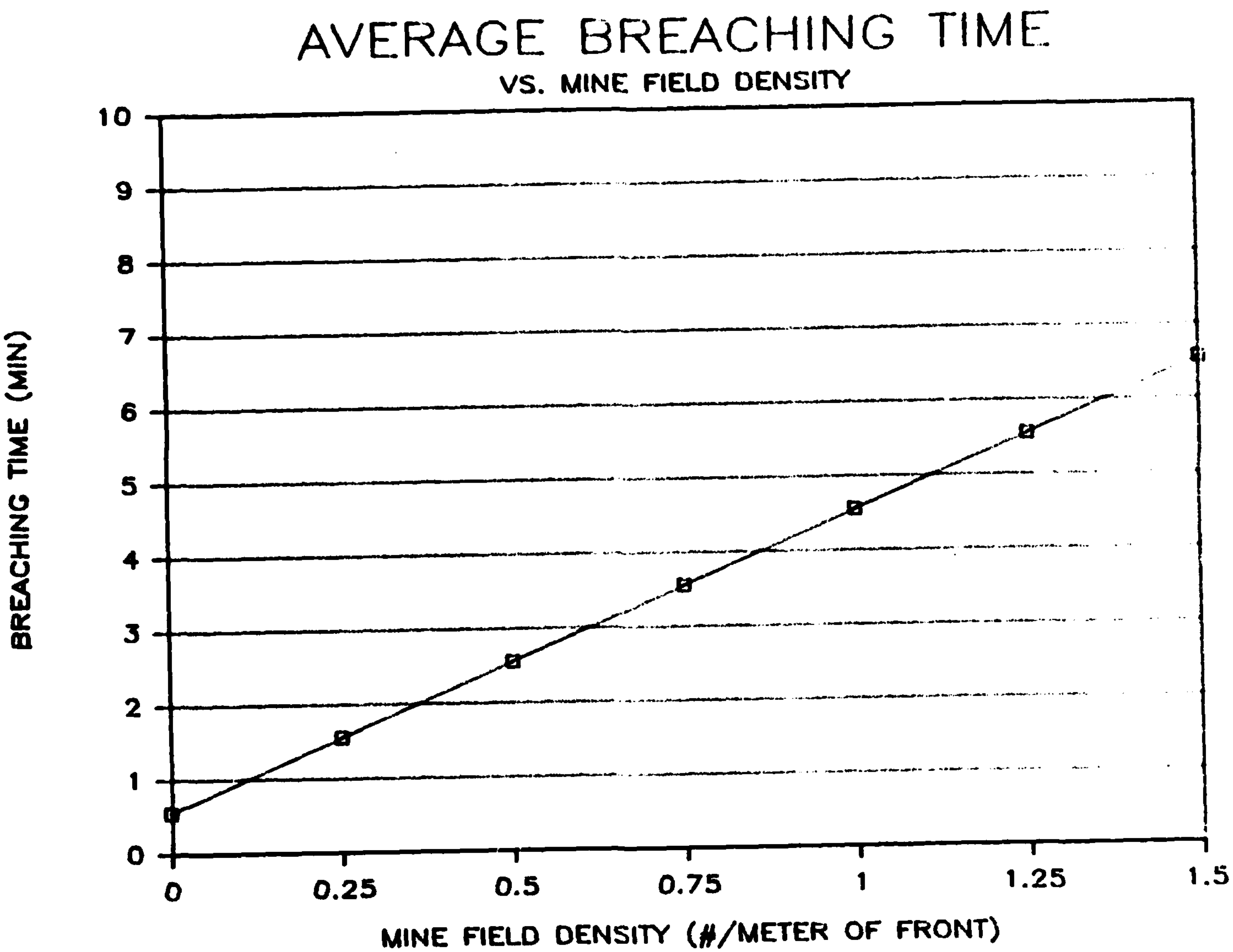


Figure V-6. Breaching Time vs. Mine Field Density

	K	L	M	N	O	CF	CG	CH
1							AVG	AVG
2	PLOW	PLOW				PROB	BREACH	CLEAR
3	WIDTH	DEPTH	PLOW	PLOW		ALL	TIME	TIME
4	(M)	(M)	SPEED	EFF.		PASS	(MIN)	(MIN)
5								
6	4	0.25	3	0		0	20.55555	41.11111
7	4	0.25	3	0.2		0.000320	16.55555	33.11111
8	4	0.25	3	0.4		0.005958	12.55555	25.11111
9	4	0.25	3	0.6		0.048348	8.555555	17.11111
10	4	0.25	3	0.8		0.250939	4.555555	9.111111
11	4	0.25	3	0.9		0.510247	2.555555	5.111111
12	4	0.25	3	1		0.978466	0.555555	1.111111
13								
14								
15								
16								
17								
18								
19								
20								

Figure V-7. Plow Effectiveness Parametric Analysis

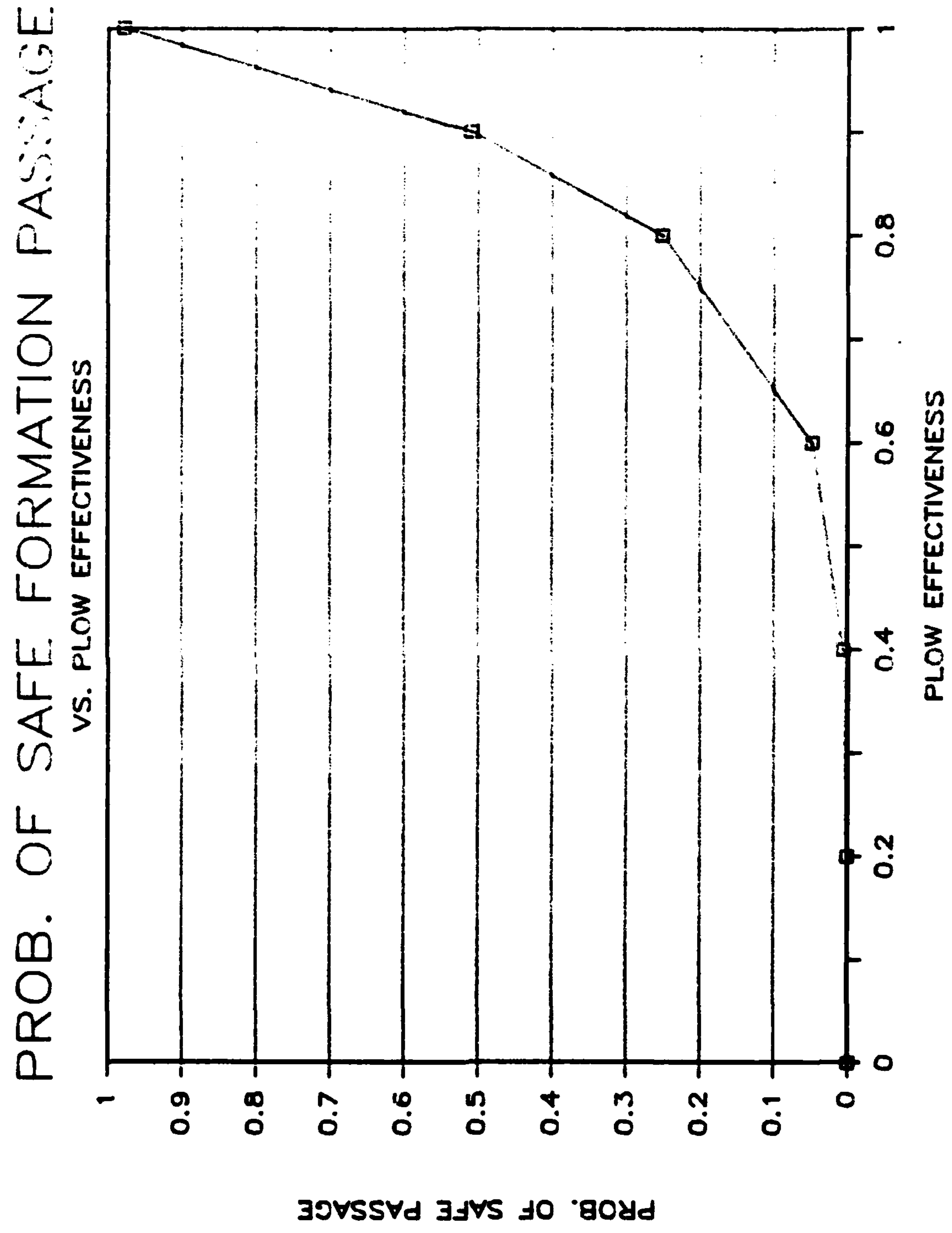


Figure V-8. Formation Survivability vs. Plow Effectiveness

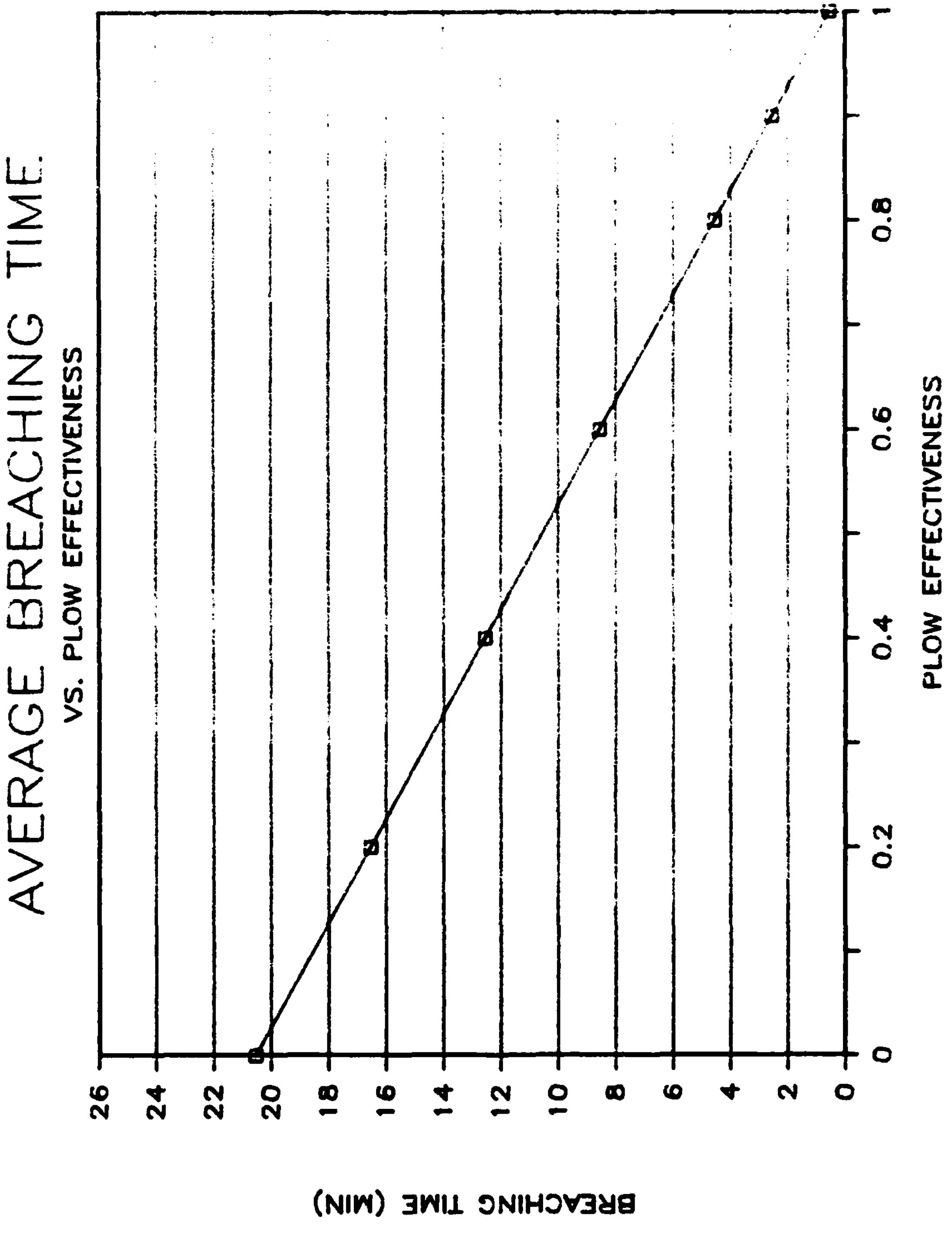


Figure V-9. Breaching Time vs. Plow Effectiveness

	W	X	Y	Z	AA		CF	CG	CH
1		NUMBER	STD.DEV	CAS.		1		AVG	AVG
2	PATH	FOLLOW	FOLLOW	TIME		2	PROB	BREACH	CLEAR
3	WIDTH	VEHICLES	VEHICLE	PENALTY		3	ALL	TIME	TIME
4	(M)		(M)	(MIN)		4	PASS	(MIN)	(MIN)
5						5			
6	5	7	0.1	20		6	0.256461	4.555555	9.111111
7	5	7	0.2	20		7	0.250939	4.555555	9.111111
8	5	7	0.3	20		8	0.216186	4.555555	9.111111
9	5	7	0.4	20		9	0.171416	4.555555	9.111111
10	5	7	0.5	20		10	0.131814	4.555555	9.111111
11	5	7	0.6	20		11	0.100663	4.555555	9.111111
12	5	7	0.7	20		12	0.077560	4.555555	9.111111
13						13			
14						14			
15						15			
16						16			
17						17			
18						18			
19						19			
20						20			

Figure V-10. Navigation Error Parametric Analysis

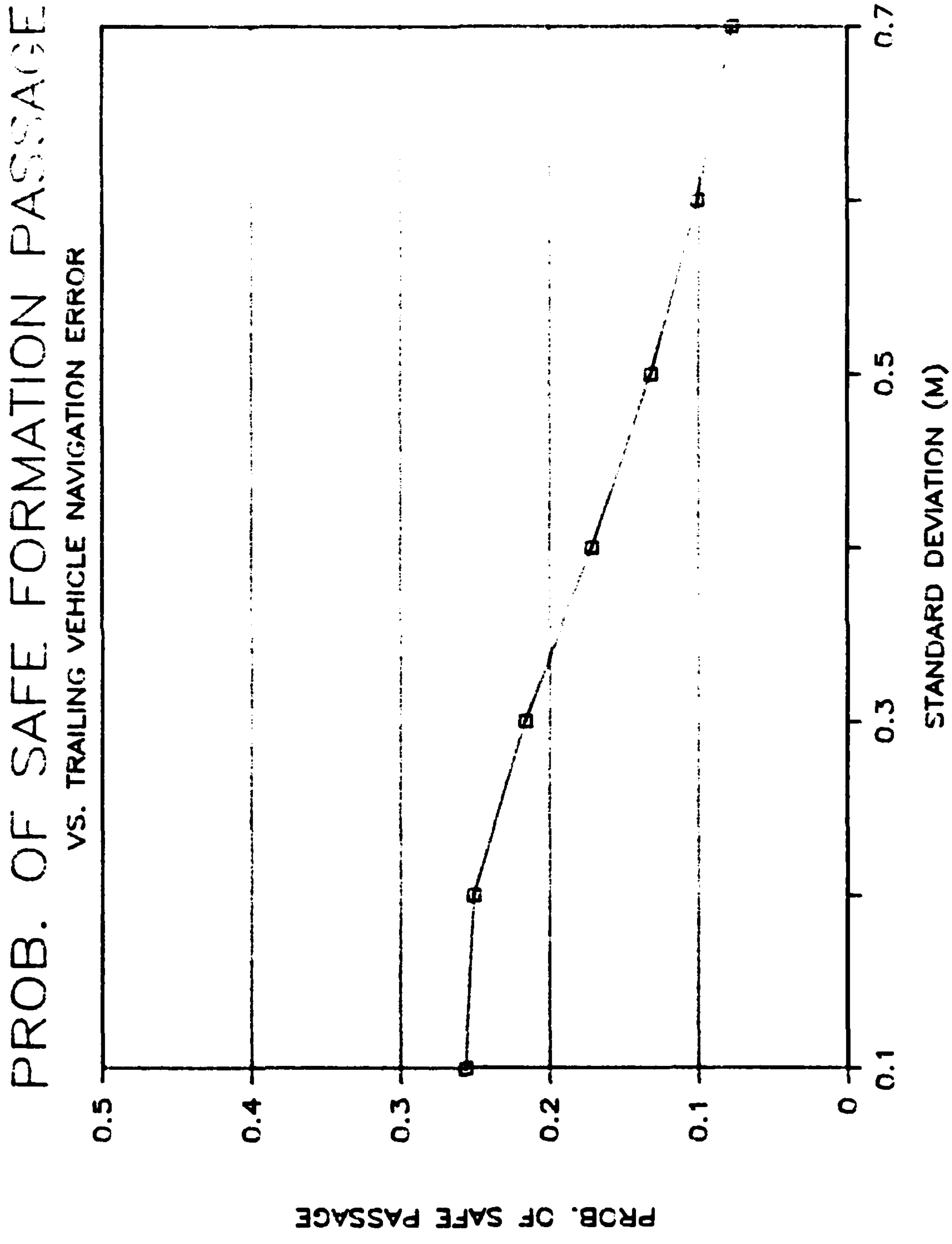


Figure V-11. Formation Survivability vs. Navigation Error

CHAPTER VI

SUMMARY

The tasks performed in this program have resulted in the following accomplishments:

(1) A low cost simulation model has been developed to evaluate the performance of alternative mine clearing plow systems. The model emphasizes ease of use, rapid computations, and effective graphical representation of results.

(2) The model has been designed to operate on a microcomputer system, specifically the IBM series of personal computers.

(3) A commercial software package, Lotus 1-2-3, was selected for the development and operation of the mine plow evaluation model. Lotus 1-2-3 has demonstrated its versatility and ease of use while supplying exceptional computational capabilities and graphical display features.

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