Bulletin 576
February 1986

An interactive simulation ogram to model feller-bunchers

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FIRST PRINTING 3M, FEBRUARY 1986

An Interactive Simulation Program To Model Feller-Bunchers

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INTRODUCTION

SIMULATION is a widely used tool for analyzing logging operations. Due to the wide variety of logging systems used and the variation among the types of forest stands harvested, simulation often offers the only way to examine certain logging situations. In general, simulation involves building a model of a system to be studied and examining how the model system reacts to changes in its operating environment.

There are two basic types of simulation.[2] The most obvious method—physical (or analog) simulation—is to build an actual working scale model and improve the design of the system by studying the scale model. This is often done by engineers before building a structure or building. This approach is not well suited to studying most logging operations. The other approach—numerical (or digital) simulation—models a system through mathematical equations which are developed after observing the system for an extended period of time. This approach has usually been employed when studying logging operations. The set of equations can be included in a computer program and different logging conditions examined with a few seconds of computer time.

Both physical and numerical simulation offer advantages and disadvantages. Many systems cannot be easily simulated with physical simulation and require the building of a scale model, which is time consuming. However, the results are often more easily interpreted and understood since the actual model can be seen and held. Numerical simulation is often more economical than physical simulation due to declining computing cost. However, efficient use of numerical

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[2]Bratley, P., B.L. Fox, and L.E. Schrage. 1983. A Guide to Simulation. Springer-Verlag, New York.

simulation requires not only a thorough knowledge of the system, but also mathematical, statistical, and programming skills. Numerical simulation results are often less easily accepted. This is often because the computer and program represent a "black box" which does not appear to respond to the input of the user.

SIMULATION APPROACH

Interactive simulation seeks to combine the advantages of both approaches. Most uses of interactive simulation display intermediate results on a graphics screen and ask the user for a response. For example, an application of interactive simulation to log merchandising displayed the outline of a tree stem on a graphics screen.[3] The user then decided how to cut the stem into logs before further processing. This type of simulation can both reduce the complexity of programming and provide easily accepted results. This can allow the use of a less expensive computer for the examination of problems which were previously difficult to study.

One logging situation which has been difficult to accurately simulate with numerical simulation is the movement of a feller-buncher in plantation thinnings. The machine must avoid the remaining trees in the stand while efficiently moving between the trees to be cut. Many logging simulators do not adequately model these machine movements.

Interactive simulation provides a better method of modelling the movements of a feller-buncher. A scale model of the machine is made of transparent plastic. This model is then moved by hand through a map of the stand. This stand map can be created by plotting a circle at the location of each tree in the stand. The size of the circle corresponds to the diameter of the tree. The stand map is then placed on a digitizing pad. The digitizing pad can detect the location of the model machine and send the location to a computer which stores the locations for later use. The computer then changes a portion of the screen display and prompts the user for the current action of the feller-buncher. Current actions include the common work elements of a feller-buncher cycle—move to tree, shear, move to dump, and dump. A series of such locations defines a path of the machine. The user simply moves the model machine, digitizes points along the path, and selects the current action of the feller-buncher. To illustrate the method, an example will be shown.

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[3]Lembersky, M.R. and U.H. Chi. 1984. "Decision Simulators" Speed Implementation and Improve Operations. Interfaces 14(4): 1-15.

USING THE PROGRAM

The example will simulate a Morbell[4] feller-buncher thinning a pine plantation, figure 1. Methods of creating a scale model machine are given in Appendix A. The stand being thinned is 23 years old and was previously thinned at age 17. Stocking before thinning averages 350 trees per acre, while thinning should reduce the stand to 140 trees per acre. The stand map represents a plot 132 feet x 132 feet (2 ch. x 2 ch.) containing 0.4 acre, figure 2. Methods of creating a stand map are presented in Appendix B.

The program splits the computer screen into three windows for displaying information, figure 3. The largest window contains a copy of the stand map that is on the digitizing pad. The two smaller windows display a summary of machine activities and messages for the user. In the stand map window, each circle represents a tree in the stand.

To begin the simulation, the user moves the scale model machine on the digitizing pad into the stand and digitizes the location of the machine while approaching the first tree to be cut. Each time a point is digitized, the machine summary window is replaced by a menu of machine actions, figure 4. The operator chooses the appropriate action by pressing a programmed key on the keyboard. Each time a point is digitized and an action selected, the machine summary is updated and displayed. Once the machine model has moved to the tree, its location is digitized and the shear action selected. The computer searches for the "cut" tree, adds the tree to the head of the feller-buncher, and updates the machine summary window. An "X" is drawn at the location of a cut tree to signify a stump. The user may now move the machine over that location since it no longer represents an obstacle.

The above procedure is repeated until the shear head is full. The user then moves the model machine to the location of the bunch to

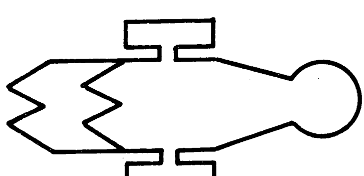

FIG. 1. A 1:120 scale model representation of the Morbell.

[4]Product names are mentioned for the reader's convenience and do not constitute an endorsement by the Alabama Agricultural Experiment Station.

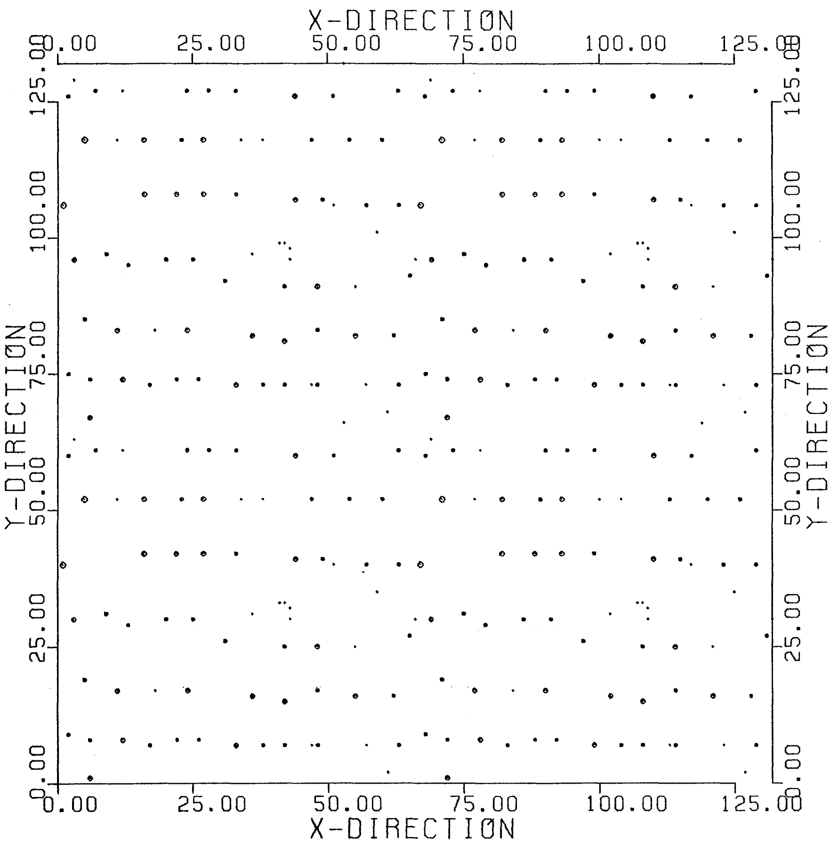

FIG. 2. A stand map representing 0.4 acre.

be built and drops the trees, figure 5. The machine summary window is cleared, showing an empty head on the machine, and the dropped trees are drawn to scale in the direction they fell on the graphics screen. The bunch now represents another obstacle for the feller-buncher to maneuver around while searching for and cutting trees.

The program contains checks to prevent the user from cutting the same tree twice and checks to see if another tree can fit into the head. However, the machine model must be moved in a realistic fashion by the user. In many ways the program accurately simulates actual conditions encountered by machine operators. The user must keep up with the number and size of trees in the head in order to make a rational decision about whether to cut another tree. If the head is nearly full, he looks for a small tree. If one is not available, he will dump his load. However, if a smaller tree is available, he may try to cut it before dropping the trees in the head. This accurately represents the activities of a feller-buncher operator.

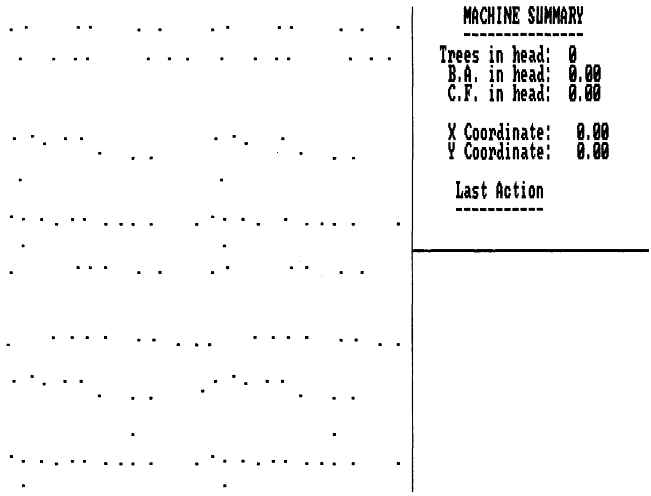

FIG. 3. Screen display at the start of simulation showing stand map, machine summary, and empty message board.

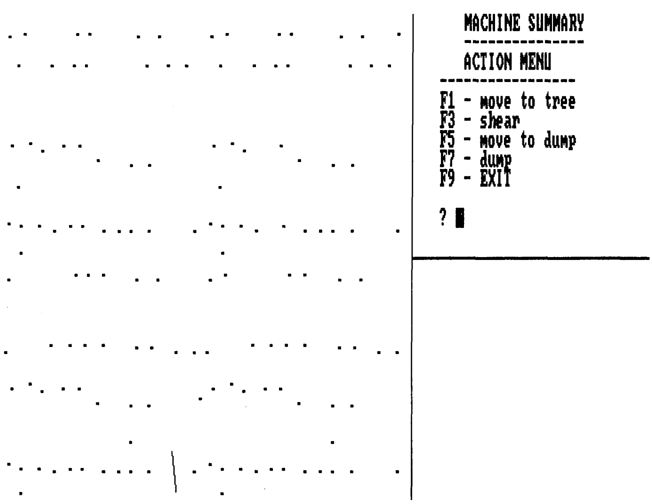

FIG. 4. Screen display with machine summary replaced by action menu after receiving a digitized machine location (bottom center).

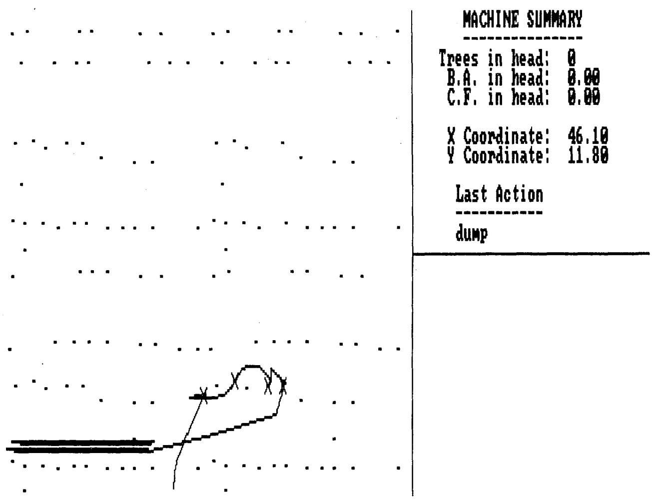

FIG. 5. Screen display after machine has cut 4 trees and started a bunch for skidding.

SAMPLE OUTPUT

When ending the simulation run, the program saves two files. One file contains the coordinates of the machine path in chronological order with their associated actions. The second file contains the coordinates and dimensions of the trees in the residual stand. These two files, along with the file containing the description of the original stand, are used in subsequent statistical summaries to measure the effectiveness of the thinning. Two general types of summaries are provided: (1) stand summaries and (2) machine summaries.

The stand summary compares the original stand to the residual stand and computes the trees, basal area, and volume removed per acre in the thinning, table 1. This is provided in the stand and stock table format commonly used by foresters to report stand information. This summary can be used to determine the quality of the thinning performed from a silvicultural standpoint or as input for economic decisions. The difference in the stand before and after thinning will provide information on removals by diameter class—an important input for estimating logging cost.

Machine summaries are provided in three parts: (1) an elemental time summary, (2) a summary by shear and dump cycles, and (3) a production summary. The elemental time summary, table 2, reports information as if a time study of the machine had been performed.

TABLE 1. STAND AND STOCK TABLE BEFORE AND AFTER THINNING

Stand/stock table, before thinning					Stand/stock table, after thinning				
DBH	*T/ac.*	*THT*	*BA/ac.*	*CD/ac.*	*DBH*	*T/ac.*	*THT*	*BA/ac.*	*CD/ac.*
6	135	43	26.5	5.7	6	5	43	1.0	0.2
7	110	47	29.4	6.8	7	43	47	11.4	2.6
8	65	52	22.7	5.5	8	53	52	18.3	4.4
9	30	57	13.3	3.3	9	30	57	13.3	3.3
10	10	62	5.5	1.4	10	10	62	5.5	1.4
Total	350		97.3	22.7	Total	140		49.4	12.0

TABLE 2. ELEMENTAL TIME SUMMARY OF SIMULATION RUN

Elemental time summary						
Element	*N*	*Mean*	*S. Dev.*	*C.V.*	*Min.*	*Max.*
Move to tree	84	0.09	0.074	81.84	0.02	0.36
Shear	84	.14	-0.000	-0.00	.14	.14
Move to dump	24	.15	.103	66.62	.01	.38
Dump	24	.32	.095	29.65	.18	.46

Feller-buncher cycles are commonly divided into four elements: (1) move to tree, (2) shear, (3) move to dump, and (4) dump. These correspond to the machine actions available while running the simulation program. In analyzing the output of the run, shear and dump times are estimated using production equations developed from previous time studies of the machine. Travel to tree and travel to dump times are computed by dividing the distance traveled by the average speed of the machine. Elemental time figures are provided since they are an accepted method of describing machine performance.

The summary by shear and dump cycles provides the most useful information from the simulation run, table 3. Information in this summary can indicate the effect of the stand on machine productivity and the ability of the operator to use the machine to its full potential. A good measure of stand effects on machine movement is provided by the "moves to tree needed" value. In maneuvering the machine model through a dense stand, more points will have to be digitized to accurately represent the machine path than would be the case in a sparsely stocked stand. A good indication of the ability of the operator to utilize the potential of the machine is provided by the "B.A. per dump" measure. This reports the basal area held by the shear head when the trees are dropped into the bunch. Feller-buncher production is often maximized when this measure reaches its maximum. The best measure of feller-buncher efficiency in this type of simulation is distance traveled. A method is more efficient than another if it cuts the same trees, but in doing so travels a shorter total distance.

The final machine summary provides the typical production figures used in comparing machines, table 4. These measures include

TABLE 3. MACHINE SUMMARY BY SHEAR AND DUMP CYCLES

Item	*Mean*	*S. Dev.*
Shear: (n = 84)		
Moves to tree needed	1.44	0.6277
Distance between shears	15.96	13.0656
Elapsed time between shears	0.09	0.0742
Dump: (n = 24)		
Moves to tree	5.04	1.4590
Moves to dump	1.42	0.6539
Trees per dump	3.50	0.7223
B.A. per dump	0.80	0.1823
C.F. per dump	16.21	3.9202
Distance between dumps	83.13	33.6146
Time between dumps	0.96	0.2630
Total distance traveled	1995.00	

TABLE 4. PRODUCTION SUMMARY FOR THE SIMULATION RUN

Machine summary	
Trees/minute	2.74
Cubic feet/productive machine hour	762.81
Cords/productive machine hour	8.48

trees per minute, cubic feet per productive machine hour, and cords per productive machine hour. These values represent a relative measure of unconstrained machine performance. As such, they are not to be taken as an accurate measure of field performance. However, comparison of these measures for different operating circumstances should provide an indication of the relative performance of the machine.

CONCLUSION

Interactive simulation is a viable method for examining the working of machines in forest stands. The method offers potential for studying the operating patterns of machines in forest stands and the effects of stand characteristics on machine performance in partial cuts.

This method[5] can be used on relatively inexpensive computer equipment with simple graphics capability without sacrificing detail. Such a method offers potential for studying and improving the work methods of operators and feller-bunchers in plantation thinnings.

[5]A copy of this interactive simulation program written in Advanced Basic (BASICA 2.10) for use on an IBM Personal Computer or compatibles is available to interested parties. Contact the authors at School of Forestry, Auburn University, Alabama 36849, for details.

APPENDIX A

Machine Models

A scale model of a feller-buncher must be made so that it properly represents the working area of the machine. The finished scale model may not necessarily resemble the machine being studied. For instance, a model of an excavator mounted machine, figure 6, does not resemble the real machine. It does, however, properly represent the working area of the machine.

In the case of the Morbell feller-buncher used as an example here, the scale model closely resembles the actual machine. This is primarily due to the tricycle design of the machine. To create a model of the Morbell, its dimensions were obtained from manufacturer's literature. The rough outline of the machine was then sketched, figure 1. The circle at the rear of the machine represents the turning radius of the rear wheel. The two V-shaped extensions on the front of the machine represent the ability of the machine to extend its cutting head without moving the machine. This extension is limited to 4.5 feet.

This model must be transferred to a transparent material (lucite or plexiglass) to be used with the simulation program. A simple model can be made by carefully scratching the outline of the machine into the material and darkening the lines to improve its appearance.

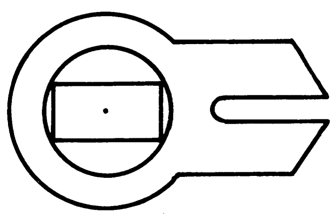

FIG. 6. A scale model of an excavator-mounted feller-buncher. (Source: Fridley, J.L., J.L. Garbini, and J.E. Jorgensen. 1982. Interactive Simulation of Forest Thinning Concepts. ASAE Paper 82-1603.)

APPENDIX B

Stand Maps

To create a stand map, a plotting program and appropriate stand data are needed. As a bare minimum, your stand data must contain the DBH and coordinates (x, y) of each tree in the stand. If this information is not available, a simulation can be run in a similar stand for which data are available or the data can be collected for the stand of interest.

Once the data are obtained, a stand map can be generated by a plotting program such as that described by Conway and others[6] or by any other graphics package. Scale should be carefully controlled so that the resulting map and the machine model are drawn to the same scale.

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[6]Conway, J.S., B.L. Lanford, B.J. Stokes, and W.D. Greene. 1985. Stand Map Plotting Program. Ala. Agr. Exp. Sta. Bull. No. 574.

APPENDIX C

Program/Hardware Interfacing

The BASIC program used for the simulation (Appendix D) was written to be used with a specific digitizer. Any digitizing tablet should work with the program. The digitizer must be able to physically connect to the computer (through a cable) and the computer must be able to understand the information sent by the digitizer.

The statement in the program which allows connection of the computer to the digitizer is:

```
1235 OPEN "com1:300,o,7,2,rs,cs0,ds0,cd0" AS #1
```

The parameters of the OPEN"COM.. statement set the baud rate, parity, number of data bits, number of stop bits, and communications protocol for the communication between digitizer and computer. Refer to the BASIC manual for your computer for details. The owners manual for your digitizer should specify the values for these parameters.

APPENDIX D

Program Listing

```
10    ' Main program.
15    '
20    KEY OFF: SCREEN 2: CLS: OPTION BASE 1
30    LOCATE 3,28: PRINT "AUBURN THINNING SIMULATOR"
35    LOCATE 4,28: PRINT "---------------"
40    LOCATE 6,28: PRINT "1 -- Run a simulation"
50    LOCATE 8,28: PRINT "2 -- Analyze data"
60    LOCATE 10,28: PRINT "3 -- Watch a simulation"
70    LOCATE 12,28: PRINT "4 -- Plotting"
80    LOCATE 14, 28: PRINT "5 -- Output data to printer"
90    LOCATE 16,28: PRINT "6 -- EXIT"
100   LOCATE 22,32: PRINT "Make a Selection"
110   LOCATE 22,48: A$=INKEY$: IF A$=" " THEN 110
120   IF ASC (A$) < 49 OR ASC (A$) > 54 THEN 110
130   A=ASC (A$)-48
140   ON A GOSUB 1000,2000,4000,5000,6000,7000

1000  '
1005  ' Main subroutine #1 -- Perform a simulation.
1010  '
1015  CLS: KEY OFF: SCREEN 2
1020  LOCATE 2,30: PRINT "PERFORM A SIMULATION"
1025  LOCATE 3,30: PRINT "--------------------"
1030  LOCATE 5,30: INPUT "Run Name       "; CODE$
1035  LOCATE 7,30: INPUT "Stand File "; STAND$
1040  PATH$=CODE$+".run": THIN$=CODE$+".map":
      STAND$=STAND$+".map"
1050  KEY 1, "move to tree"+CHR$ (13) : KEY 3, "shear"+CHR$ (13)
1055  KEY 5, "move to dump"+CHR$ (13): KEY 7, "dump"+CHR$ (13): KEY 9,
      "exit"+CHR$ (13)
```

```
1060 KEY 2, "": KEY 4, "": KEY 6, "": KEY 8,"": KEY 10,""
1065 SYMBOL$ = "ne3 nf3 ng3 nh3"
1070 CT = 0: X0 = 0: Y0 = 0: PT = 0: XMAX = 132: YMAX = 132: SCALE = 10
1075 OPEN STAND$ FOR INPUT AS #1
1080 WHILE NOT EOF (1)
1085 CT = CT + 1
1090 LINE INPUT#1, Z$
1095 WEND
1100 CLOSE #1
1105 DIM X (CT), Y (CT), DBH (CT), THT (CT), CUFT (CT), SDIA (CT), CC
     (CT), HT (9)
1110 CLS
1115 ' Draw stand map on left side of screen.
1120 '
1125 OPEN STAND$ FOR INPUT AS #1
1130 LINE (404,0) - (404,199): LINE (404,100) - (639,100)
1135 WINDOW (0,0) - (XMAX,YMAX): VIEW (0,0) - (399,199)
1140 FOR I = 1 TO CT
1145 INPUT#1, TREE,X,Y,DBH,THT,SDIA,CUFT
1150 X (I) = X: Y(I) = Y: DBH (I) = DBH: THT (I) = THT: SDIA (I) = SDIA: CUFT
     (I) = CUFT: CC (I) = 1
1155 R = DBH/24 : CIRCLE (X,Y),R
1160 NEXT I
1165 CLOSE #1: X = 0: Y = 0
1170 '
1175 ' Display summary information on screen.
1180 '
1185 VIEW: WINDOW (0,0) - (639,199)
1190 LOCATE 1,58: PRINT "MACHINE SUMMARY"
1195 LOCATE 2,58: PRINT "----------------"
1200 GOSUB 1510
1205 'Open files for storing machine path and thinned stand.
1210 '
1215 OPEN PATH$ FOR OUTPUT AS #2
1220 OPEN THIN$ FOR OUTPUT AS #3
1225 ' Open communications buffer to receive digitized points.
1230 '
1235 OPEN "com1:300,o,7,2,rs,cs0,ds0,cd0" AS #1
1240 COM (1) ON
1245 ON COM (1) GOSUB 1320
1250 GOTO 1245
1255 VIEW (407,103) - (639,199): CLS: LOCATE 19,60: PRINT "Please Wait"
1260 CLOSE#1: CLOSE#2
1265 '
1270 ' Store thinned stand.
1275 FOR I = 1 TO CT
1280 IF CC (I) = 0 THEN 1290
1285 WRITE#3,I,X(I),Y(I),DBH(I),THT(I),SDIA(I),CUFT(I)
1290 NEXT I
1295 CLOSE #3
1300 '
```

```
1305 ' Reset soft keys to defaults.
1310 KEY 1, "list": KEY 2, "run"+CHR$ (13): KEY 3, "load"+CHR$ (34):
     KEY 4, "save"+CHR$ (34): KEY 5, "cont"+CHR$ (13):
     KEY 6, ","+CHR$ (34)+"1ptl:"+CHR$ (34)+CHR$ (13):
     KEY 7, "tron"+CHR$ (13): KEY 8, "troff"+CHR$ (13):
     KEY 9, "key": KEY 10, "screen 0,0,0"
1315 VIEW: CLS: CLEAR: GOTO 30
1320 '
1325 ' Read communications buffer.
1330 INPUT#1,X,Y
1335 IF Y>YMAX/SCALE THEN RETURN
1340 PT=PT+1: X=X*SCALE: Y=Y*SCALE
1345 IF PT=1 THEN D=0 ELSE D=INT (SQR ( (X-X0)2+(Y-Y0)2) )
1350 GOSUB 1370      ' Draw movement on screen.
1355 GOSUB 1390      ' Update machine summary.
1360 RETURN
1365 '
1370 ' Draw movement on screen.
1375 VIEW (0,0) - (399,199) : WINDOW (0,0) - (XMAX, YMAX)
1380 IF PT=1 THEN PSET (X,Y) ELSE LINE (X0,Y0) - (X,Y)
1382 VIEW (407,103) - (639,199): CLS
1385 RETURN
1390 '
1395 ' Update machine summary.
1400 VIEW (409,16) - (639,97): CLS: VIEW: WINDOW (0,0) - (639,199)
1405 LOCATE 3,55: PRINT "   ACTION MENU"
1410 LOCATE 4,55: PRINT "-------------"
1415 LOCATE 5,55: PRINT "F1 - move to tree"
1420 LOCATE 6,55: PRINT "F3 - shear"
1425 LOCATE 7,55: PRINT "F5 - move to dump"
1430 LOCATE 8,55: PRINT "F7 - dump"
1435 LOCATE 9,55: PRINT "F9 - EXIT"
1440 LOCATE 11,55: INPUT ; ACTION$
1445 IF ACTION$<>"exit" THEN 1470
1450 BEEP: BEEP: BEEP: BEEP
1455 VIEW (407,103) - (639,199): CLS:
     LOCATE 19,58: INPUT "Are You Sure" ; E$
1460 IF E$="Y" OR E$="y" THEN 1255
1465 IF E$="N" OR E$="n" THEN 1390 ELSE 1450
1470 IF ACTION$="shear" THEN 1595
1475 IF ACTION$="dump" THEN 1710
1480 IF ACTION$="move to tree" THEN A=1
1485 IF ACTION$="move to dump" THEN A=3
1490 ' replace menu with updated machine summary
1495 '
1500 X0=X: Y0=Y
1505 WRITE#2,PT,X,Y,D,A
1510 VIEW (409,16) - (639,97): CLS
1515 VIEW: WINDOW (0,0) - (639,199)
1520 LOCATE 3,55 : PRINT "Trees in head: " THD
1525 LOCATE 4,55 : PRINT "B.A. in head: "
```

```
1530 LOCATE 4,70 : PRINT USING "##.##"; BAHD
1535 LOCATE 5,55 : PRINT "C.F. in head: "
1540 LOCATE 5,70 : PRINT USING "##.##"; CFHD
1545 LOCATE 6,55 : PRINT "                    "
1550 LOCATE 7,55 : PRINT " X Coordinate: "
1555 LOCATE 7,70 : PRINT USING "###.##"; X
1560 LOCATE 8,55 : PRINT " Y Coordinate: "
1565 LOCATE 8,70 : PRINT USING "###.##"; Y
1570 LOCATE 9,55 : PRINT
1575 LOCATE 10,55 : PRINT " Last Action "
1580 LOCATE 11,55 : PRINT "--------------"
1585 LOCATE 12,55 : PRINT "" ACTION$
1590 RETURN
1595 ' Shear function just completed.
1600 A=2
1605 VIEW (0,0) - (399,199): WINDOW (0,0) - (XMAX,YMAX)
1610 CC=0
1615 ' find cut tree, add tree to head, remove tree from stand
1620 FOR I=1 TO CT
1625 IF CC(I)=0 THEN 1680
1630 XCHK=X-X (I)
1635 IF (XCHK>= - 1.5) AND (XCHK<=1.5) THEN 1640 ELSE 1680
1640 YCHK=Y-Y (I)
1645 IF (YCHK>-1.5) AND (YCHK<=1.5) THEN 1650 ELSE 1680
1650 CC=1: CC(I)=0: THD=THD+1
1655 BAHD=BAHD+.005454*(DBH(I)^2)
1660 CFHD=CFHD+CUFT(I)
1665 PSET (X(I), Y(I) ): DRAW SYMBOL$
1670 HT (THD)=THT(I): D=DBH(I)
1675 I=CT
1680 NEXT I
1685 IF CC=1 THEN 1705
1690 BEEP: BEEP: BEEP: BEEP
1695 VIEW (407,103) - (639,199): CLS: LOCATE 19,58: PRINT "Tree Not Found"
1700 ACTIONS$="move to tree": D=INT (SQR ( (X-X0)^2+(Y-Y0)^2) )
1705 GOTO 1490
1710 ' Dump function just completed.
1715 A=4
1720 R=SQR ( (X-X0))^2+(Y-Y0))^2)
1725 CS=(X-X0)/R : SN=(Y-Y0)/R
1730 XB=.5*CS+X : YB=.5*SN+Y
1735 VIEW (0,0) - (399,199): WINDOW (0,0) - (XMAX, YMAX)
1740 FOR I=1 TO THD
1745 XI=HT(I)*CS+XB : YT=HT(I)*SN+YB
1750 LINE (XB, YB) - (XT, YT)
1755 XB=XB+1: YB=YB+1
1760 NEXT I
1765 THD=0: BAHD=0: CFHD=0
1770 GOTO 1490

2000 '
```

```
2005 ' Main subroutine #2 — Analyze Data.
2010 '
2015 KEY OFF: SCREEN 2
2020 CLS: CLEAR
2025 LOCATE 2,34: PRINT "ANALYZE DATA"
2030 LOCATE 3,34: PRINT "------------"
2035 LOCATE 6,29: PRINT "1—Stand Data Only"
2040 LOCATE 8,29: PRINT "2—Machine Path Only"
2045 LOCATE 10,29: PRINT "3—Summarize a Run"
2050 LOCATE 12,29: PRINT "4—EXIT"
2055 LOCATE 15,32: PRINT "Make a Selection"
2060 LOCATE 15,48: A$=INKEY$: IF A$="" THEN 2060
2065 IF ASC (A$)<49 OR ASC(A$)>53 THEN 2060
2070 A=ASC(A$)-48
2075 ON A GOTO 2080, 2270, 2315, 30
2080 '
2085 ' Analyze stand data.
2090 CLS: LOCATE 2,31: PRINT "Analyze Stand Data"
2095 LOCATE 3,31: PRINT "------------------"
2100 LOCATE 6,30: PRINT "1—Single Stand"
2105 LOCATE 8,30: PRINT "2—Compare Two Stands"
2110 LOCATE 10,30: PRINT "3—EXIT"
2115 LOCATE 12,1: A$=INKEY$: IF A$="" THEN 2115
2120 IF ASC(A$)<49 OR ASC (A$)>51 THEN 2115
2125 A=ASC(A$)-48
2130 ON A GOTO 2135, 2185, 2020
2135 '
2140 ' Single stand.
2145 CLS: LOCATE 2,34: PRINT "Single Stand"
2150 LOCATE 3,34: PRINT "------------"
2155 LOCATE 8,25: INPUT "Name of stand file" ; STAND$
2160 LOCATE 10,25: INPUT "Plot size (acres)" ; PLOTSIZE
2165 LOCATE 15,34: PRINT "Please Wait"
2170 GOSUB 2390
2175 GOTO 2020
2180 '
2185 ' Compare two stands.
2190 CLS: LOCATE 2,31: PRINT "Compare Two Stands"
2195 LOCATE 3,31: PRINT "------------------"
2200 LOCATE 6,20: INPUT "Is this a before/after comparison (Y/N)" ; A$
2205 IF A$="Y" OR A$="y" THEN 2240
2210 LOCATE 8,30: INPUT "Name of stand file #1" ; BEFORE$
2215 LOCATE 10,30: INPUT "Name of stand file #2" ; AFTER$
2220 LOCATE 12,30: INPUT "Plot size (acres)" ; PLOTSIZE
2225 LOCATE 15,34: PRINT "Please Wait"
2230 GOSUB 2390
2235 GOTO 2020
2240 LOCATE 8,30: INPUT "Name of stand file before" ; BEFORE$
```

```
2245 LOCATE 10,30: INPUT "Name of stand file after" ; AFTER$
2250 LOCATE 12,30: INPUT "Plot size (acres)" ; PLOTSIZE
2255 LOCATE 15,34: PRINT "Please Wait"
2260 GOSUB 2390
2265 GOTO 2020
2270 '
2275 ' Analyze machine path.
2280 CLS: LOCATE 2,30: PRINT "Analyze Machine Path"
2285 LOCATE 3,30: PRINT "--------------------"
2290 LOCATE 8,31: INPUT "Name of path file" ; PATH$
2295 LOCATE 15,34: PRINT "Please Wait"
2300 GOSUB 2930
2305 GOTO 2020
2310 '
2315 ' Summarize a run.
2320 CLS: LOCATE 2,32: PRINT "Summarize a Run"
2325 LOCATE 3,32: PRINT "---------------"
2330 LOCATE 6,20: INPUT "Name of original stand file" ; BEFORE$
2335 LOCATE 8,20: INPUT "Name of residual stand file" ; AFTER$
2340 LOCATE 10,20: INPUT "Plot size (acres) " ; PLOTSIZE
2345 LOCATE 12,20: INPUT "Name of machine path file " ; PATH$
2350 LOCATE 15,34: PRINT "Please Wait": A=2
2355 GOSUB 2390
2360 LOCATE 15,34: PRINT "Please Wait"
2365 GOSUB 2930
2370 GOTO 2020
2375 '
2380 ' Stand Analysis subroutines.
2385 '
2390 DIM N(A,18), SHT(A,18), SCF(A,18), XDBH(2), NDBH(2), TPA(2), BAPA(2),
     CDPA(2)
2395 AX=1
2400 IF A=1 THEN 2410
2405 IF AX=1 THEN STAND$=BEFORE$
2410 XDBH(AX)=0: NDBH (AX)=12
2415 OPEN STAND$ FOR INPUT AS #1
2420 WHILE NOT EOF(1)
2425 INPUT#1, TREE, X, Y, DBH, THT, SDIA, CUFT
2430 DCL=INT(DBH+.49)
2435 N(AX,DCL)=N(AX,DCL)+1
2440 SHT(AX,DCL)=SHT(AX,DCL)+THT
2445 SCF(AX,DCL)=SCF(AX,DCL)+CUFT
2450 IF DCL >= NDBH(AX) THEN 2460
2455 NDBH(AX)=DCL: GOTO 2470
2460 IF DCL <= XDBH(AX) THEN 2470
2465 XDBH(AX)=DCL
2470 WEND
2475 CLOSE #1
2480 IF A=1 THEN 2495
2485 IF AX=1 THEN AX=2 ELSE 2495
2490 STAND$=AFTER$: GOTO 2410
```

```
2495 BEEP: CLS: LINE (0,9) - (639,9): LINE (323,9) - (323,199): AX=1: Z=0
2500 IF A=1 THEN 2520
2505 IF A$="N" OR A$="n" THEN 2515
2510 LOCATE 1,17: PRINT "BEFORE": LOCATE 1,57: PRINT "AFTER":
     GOTO 2520
2515 LOCATE 1,15: PRINT "STAND #1": LOCATE 1,55: PRINT "STAND #2"
2520 LOCATE 4,11+Z: PRINT "STAND/STOCK TABLE"
2525 LOCATE 6,2+Z: PRINT "DBH": LOCATE 6,10+Z: PRINT "T/Ac."
2530 LOCATE 6,18+Z: PRINT "THT": LOCATE 6,24+Z: PRINT "BA/Ac."
2535 LOCATE 6,33+Z: PRINT "CD/Ac."
2540 LOCATE 7,2+Z: PRINT "--------------------------------------"
2545 ROW=8
2550 FOR DCL=NDBH(AX) TO XDBH(AX)
2555 LOCATE ROW,2+Z: PRINT USING "###" ; DCL
2560 MHT=SHT (AX,DCL)/N(AX,DCL)
2565 N (AX,DCL)=N(AX,DCL)/PLOTSIZE
2570 TPA(AX)=TPA(AX)+N(AX,DCL)
2575 LOCATE ROW, 11+Z: PRINT USING "###"; N(AX,DCL)
2580 LOCATE ROW, 18+Z: PRINT USING "###"; MHT
2585 BA=.0054542*DCL^2*N(AX,DCL)
2590 BAPA(AX)=BAPA(AX)+BA
2595 LOCATE ROW, 25+Z: PRINT USING "##.#"; BA
2600 CORDS=SCF(AX,DCL)/90/PLOTSIZE
2605 CDPA(AX)=CDPA(AX)+CORDS
2610 LOCATE ROW, 34+Z: PRINT USING "##.#"; CORDS
2615 ROW=ROW+1
2620 NEXT DCL
2625 LOCATE ROW, 2+Z: PRINT "--------------------------------------"
2630 ROW=ROW+1
2635 LOCATE ROW, 2+Z: PRINT "TOTAL"
2640 LOCATE ROW, 11+Z: PRINT USING "###"; TPA(AX)
2645 LOCATE ROW, 24+Z: PRINT USING "###.#"; BAPA(AX)
2650 LOCATE ROW, 34+Z: PRINT USING "##.#"; CDPA(AX)
2655 IF A=1 THEN 2675
2660 IF (A=2) AND (AX=2) THEN 2670
2665 AX=2: Z=40: GOTO 2520
2670 IN INKEY$="" THEN 2670 ELSE 2680
2675 AX=1: S=2: GOTO 2685
2680 AX=1: S=1
2685 ' Histogram plot.
2690 IF S=2 THEN 2700
2695 VIEW (0,15) - (319,199): CLS: WINDOW (0,0) - (311,183): GOTO 2705
2700 VIEW (327,15) - (639,199): CLS: WINDOW (0,0) - (311,183)
2705 ' Draw axes.
2710 LINE (315,27) - (35,27): LINE - (35,163)
2715 IF AX=2 THEN 2780
2720 ' Scale x-axis.
2725 NB=XDBH(AX)-NDBH(AX)+1  'Number of bars
2730 DBB=INT (280/NB)  'Distance between bar centers
2735 BW=INT(.5*DBB)  'Bar width
2740 ' Scale y-axis.
```

```
2745 YMAX=0 'Determine maximum y-value
2750 FOR DCL=NDBH(AX) TO XDBH(AX)
2755 IF YMAX>N(AX,DCL) THEN 2765
2760 YMAX=N(AX,DCL)
2765 NEXT DCL
2770 DBT=18 'Distance between tick marks (dots)
2775 YCL=INT(YMAX/6) 'Y-value increment on y-axis
2780 IF S=1 THEN Z=6 ELSE Z=47
2785 FOR DCL=NDBH(AX) TO XDBH(AX)
2790 COL=Z+INT(DBB/8)*(DCL-NDBH(AX))
2795 LOCATE 23,COL : PRINT USING "##"; DCL
2800 NEXT DCL
2805 YTICK=0
2810 Y=31
2815 WHILE Y <= 175
2820 ROW=26-(Y+1)/8: LOCATE ROW, 1+(S-1)*41: PRINT USING "###";
     YTICK
2825 LINE (24,Y)-(27,Y)
2830 Y=Y+DBT: YTICK=YTICK+YCL
2835 WEND
2840 ' Label x-axis.
2845 LOCATE 24,20+(S-1)*41: PRINT "DBH";
2850 ' Label y-axis.
2855 LOCATE 3,1+(S-1)*41: PRINT "T/Ac."
2860 ' Plot histogram bars
2865 FOR DCL=NDBH(AX) TO XDBH(AX)
2870 X=55+INT (DBB/8)*8*(DCL-NDBH(AX))
2875 HT=N(SX,DCL)/YMAX*128
2880 TOP=31+HT
2885 LEFT=X-INT(BW/2)
2890 RIGHT=LEFT+2*INT(BW/2)
2895 LINE (LEFT,27)-(RIGHT,TOP), ,BF
2900 NEXT DCL
2905 S=S+1
2910 IF S<>2 THEN 2920
3435 LOCATE 7,50: PRINT USING "####.##"; TCF/RT*60
3440 LOCATE 9,50: PRINT USING "####.##"; TCF/RT/90*60
3445 IF INKEY$="" THEN 3445
3450 CLEAR: SCREEN 2: GOTO 2370
3455 '
3460 ' A=1 — Move to tree element.
3465 T=D/SPEED(A)
3470 MBS=MBS+1
3475 DBS=DBS+D
3480 TBS=TBS+T
3485 TMBD=TMBD+1
3490 DBD=DBD+D
3495 TBD=TBD+T
3500 RETURN 2995
3505 '
3510 ' A=2 — Shear element.
```

```
3515 IF D<8.5 THEN T=.1381 ELSE T=.1381+.003*(D^2-72.25)
3520 SMBS=SMBS+MBS
3525 SSMBS=SSMBS+MBS^2
3530 SDBS=SDBS+DBS
3535 SSDBS=SSDBS+DBS^2
3540 STBS=STBS+TBS
3545 SSTBS=SSTBS+TBS^2
3550 MBS=0: DBS=0: TBS=0
3555 TPH=TPH+1
3560 BA=.0054542*D^2
3565 CF=-1.306+.078*D+.1299*D^2
3570 BAPH=BAPH+BA
3575 CFPH=CFPH+CF
3580 TCF=TCF+CF
3585 TBD=TBD+T
3590 RETURN 2995
3595 '
3600 ; A=3 — Move to dump element.
3605 T=D/SPEED(A)
3610 DMBD=DMBD+1
3615 DBD=DBD+D
3620 TBD=TBD+T
3625 RETURN 2995
3630 '
3635 ; A=4 — Dump element.
3640 IF A=4 THEN T=.0569+.0162*CFPH
3645 STMBD=STMBD+TMBD
3650 SSTMBD=SSTMBD+TMBD^2
3655 SDMBD=SDMBD+DMBD
3660 SSDMBD=SSDMBD+DMBD^2
3665 STBD=STBD+TBD
3670 SSTBD=SSTBD+TBD^2
3675 SDBD=SDBD+DBD
3680 SSDBD=SSDBD+DBD^2
3685 TMBD=0: TBD=0: DBD=0: DMBD=0
3690 STPH=STPH+TPH
3695 SSTPH=SSTPH+TPH^2
3700 SBAPH=SBAPH+BAPH
3705 SSBAPH=SSBAPH+BAPH^2
3710 SCFPH=SCFPH+CFPH
3715 SSCFPH=SSCFPH+CFPH^2
3720 TPH=0: BAPH=0: CFPH=0
3725 RETURN 2995
3730 '
3735 ' Print information on screen #2.
3740 LOCATE ROW,50: PRINT USING "####.##"; MEAN
3745 LOCATE ROW,60: PRINT USING "####.##"; SDEV
3750 RETURN

4000 ' Main subroutine #3. — Observe a simulation.
4010 '
```

```
4020 CLS: KEY OFF: SCREEN 2: XMAX=132: YMAX=132
4030 LOCATE 2,29: PRINT “OBSERVE A SIMULATION”
4040 LOCATE 3,29: PRINT “--------------------”
4050 LOCATE 6,20: INPUT “Machine path file”; PATH$
4060 LOCATE 8,20: PRINT “Original stand file”; STAND$
4070 LOCATE 12,35: PRINT “Please Wait”
4080 OPEN STAND$ FOR INPUT AS #1 ’ Count number of trees in stand.
4090 WHILE NOT EOF (1)
4100 CT=CT+1: LINE INPUT#1,Z$
4110 WEND
4120 CLOSE #1
4130 DIM X(CT), Y(CT), DBH(CT), THT(CT), CUFT(CT), SDIA(CT), CC(CT),
     HT(9): CLS
4140 SYMBOL$=“ne2 nf2 ng2 nh2”
4150 LINE (404,0) - (404,199) ‘ LINE (404,100) - (639,100)
4160 WINDOW (0,0) - (XMAX, YMAX) : VIEW (0,0) - (399,199)
4170 OPEN STAND$ FOR INPUT AS #1
4180 FOR I=1 TO CT
4190 INPUT#1, TREE, X, Y, DBH, THT, SDIA, CUFT
4200 X(I)=X: Y(I)=Y: DBH(I)=DBH: THT(I)=THT: SDIA(I)=SDIA:
     CUFT(I)=CUFT: CC(I)=1
4210 R=DBH/24: CIRCLE (X,Y), R
4220 NEXT I
4230 CLOSE #1: X=0: Y=0
4240 VIEW: WINDOW (0,0) - (639,199)
4250 LOCATE 1,58: PRINT “MACHINE SUMMARY”: LOCATE 2,58: PRINT
     “---------------”
4260 LOCATE 3,55: PRINT “Trees in head:’
4270 LOCATE 4,55: PRINT “B.A. in head:”
4280 LOCATE 5,55: PRINT “C.F. in head:”
4290 LOCATE 7,55: PRINT “X Coordinate:”
4300 LOCATE 8,55: PRINT “Y Coordinate:”
4310 LOCATE 10,55: PRINT “Last Action ”
4320 LOCATE 11,55: PRINT “-----------”
4330 OPEN PATH$ FOR INPUT AS #1
4340 WHILE NOT EOF(1)
4350 WINDOW (0,0) - (XMAX,YMAX): VIEW (0,0) - (339,199)
4360 INPUT#1,PT,X,Y,D,A,
4370 ’ IF PT=1 THEN PSET (X,Y) ELSE LINE (X0,Y0) - (X,Y)
4380 ON A GOSUB 4460, 4570, 4460, 4760
4390 GOSUB 4480
4400 FOR I=1 TO 500 : NEXT I
4410 X0=X: Y0=Y
4420 WEND
4430 LOCATE 19,60: PRINT “Run ended”
4440 IF INKEY$=“” THEN 4430
4450 CLS: GOTO 30
4460 IF A=1 THEN ACTION$=“move to tree” ELSE ACTION$=“move to
     dump”
4470 RETURN
4480 VIEW: WINDOW (0,0) - (639,199)
```

```
4490 LOCATE 3,70 : PRINT USING "##"; THD
4500 LOCATE 4,55 : PRINT "B.A. in head:"
4510 LOCATE 4,70 : PRINT USING "##.##"; BAHD
4520 LOCATE 5,70 : PRINT USING "##.##"; CFHD
4530 LOCATE 7,70 : PRINT USING "###.##"; X
4540 LOCATE 8,70 : PRINT USING "###.##"; Y
4550 LOCATE 12,55 : PRINT "                ": LOCATE 12,55: PRINT ACTION$
4560 RETURN
4570 ' Shear function just completed.
4580 ACTION$ = "shear"
4590 VIEW (0,0) - (399,199): WINDOW (0,0) - (XMAX,YMAX)
4600 THD=THD+1
4610 ' Find cut tree in list, add tree to head, and remove tree from stand.
4620 FOR I=1 TO CT
4630 IF CC(I)=0 THEN 4740
4640 XCHK=X-X(I)
4650 IF (XCHK >=-.15) AND (XCHK <= 1.5) THEN 4660 ELSE 4740
4660 YCHK=Y-Y(I)
4670 IF (YCHK >= -1.5) AND (YCHK <= 1.5) THEN 4680 ELSE 4740
4680 CC(I)=0
4690 BAHD=BAHD+.005454*(DBH(I)^2)
4700 CFHD=CFHD+CUFT(I)
4710 PSET (X(I),Y(I) ): DRAW SYMBOL$
4720 HT(THD)=THT(I): D=DBH(I)
4730 I=CT
4740 NEXT I
4750 RETURN
4760 ' Dump function just completed.
4770 ACTION$ = "dump"
4780 R=SQR((X-X0)^2+(Y-Y0)^2)
4790 CS=(X-X0)/R :SN=(Y-Y0)/R
4800 XB/=.5*CS+X : YB=.5*SN+Y
4810 VIEW (0,0) - (399,199): WINDOW (0,0) - (XMAX,YMAX)
4820 FOR I=1 TO THD
4830 XT=HT (I)*CS+XB : YT=HT (I)*SN+YB
4840 LINE (XB,YB) - (XT,YT)
4850 XB=XB+.5: YB=YB+.5
4860 NEXT I
4870 THD=0: BAHD=0: CFHD=0
4880 RETURN

5000 '
5010 ' Main subroutine #4 — Plotting.
5020 '
5030 CLS: KEY OFF
5040 LOCATE 2,36: PRINT "PLOTTING": LOCATE 3,36: PRINT "--------"
5050 LOCATE 12,30: PRINT "NOT CURRENTLY ACTIVE"
5060 IN INKEY$="" THEN 5060
5070 GOTO 30

6000 '
```

```
6010 ' Main subroutine #6 — Generate a data listing.
6020 '
6030 CLS: KEY OFF
6040 LOCATE 2,28: PRINT "GENERATE A DATA LISTING."
6050 LOCATE 3,28: PRINT "------------------------"
6060 LOCATE 5,26: PRINT "1 — Output stand map data"
6070 LOCATE 8,26: PRINT "2 —Output machine path data"
6080 LOCATE 11,26: PRINT "3 — EXIT"
6090 LOCATE 16,26: PRINT "Enter your selection"
6100 LOCATE 16,48: A$=INKEY$: IF A$="" THEN 6100
6110 IF ASC(A$)<49 OR ASC(A$)>51 THEN 6100
6120 A=ASC(A$)-48
6130 ON A GOSUB 6150, 6370, 6580
6140 GOTO 6030
6150 '
6160 ' Output stand map data.
6170 '
6180 CLS
6190 LOCATE 2,29: PRINT "Output stand map data."
6200 LOCATE 3,29: PRINT "-------------------"
6210 LOCATE 5,29: INPUT "Enter stand file name:; STAND$
6220 LOCATE 8,16: PRINT "Turn on printer. .Line up paper. .Strike any key"
6230 IF INKEY$="" THEN 6230
6240 OPEN STAND$ FOR INPUT AS #1
6250 LPRINT "STAND MAP DATA" TAB (40) "FILE: " STAND$: LPRINT
6260 LPRINT "Tree #" TAB(10) "X-Coord." TAB(20) "Y-Cord." TAB(30) "DBH"
     TAB (40) "THT" TAB(50) "SDIA" TAB (60) "C.F. Vol."
6270 LPRINT "------" TAB(10) "--------" TAB(20) "--------" TAB(30) "---" TAB(40) "-
     --" TAB(50) "----" TAB(60) "----------"
6280 FOR I=1 TO 55
6290 IF EOF(1) THEN 6350
6300 INPUT#1, TREE,X,Y,DBH,THT,SDIA,CUFT
6310 LPRINT TREE TAB(10) X TAB (20) Y TAB (30) DBH TAB (40) THT TAB (50)
     SDIA TAB (60) CUFT
6320 NEXT I
6330 LPRINT CHR$(12)
6340 GOTO 6260
6350 LPRINT CHR$(12)
6360 CLOSE#1: RETURN
6370 '
6380 ' Output a machine path file.
6390 '
6400 CLS: LOCATE 2,28: PRINT "Output machine path data."
6410 LOCATE 3,28: PRINT "-----------------------"
6420 LOCATE 5,28: INPUT "Enter machine path file"; PATH$
6430 LOCATE 10,16: PRINT "Turn on printer. .Line up paper. .Strike any key"
6440 IF INKEY$="" THEN 6440
6450 OPEN PATH$ FOR INPUT AS #1
6460 LPRINT "MACHINE PATH DATA" TAB(40) "FILE: " PATH$: LPRINT
6470 LPRINT "Point #" TAB(10) "X-Coord." TAB(20) "Y-Coord." TAB(30)
     "Distance" TAB(45) "Action Taken"
```

```
6480  LPRINT "-------" TAB(10) "--------" TAB(20) "--------" TAB(30) "--------"
      TAB (42) "------------------"
6490  FOR I=1 TO 55
6500  IF EOF(1) THEN 6560
6510  INPUT#1,PT,X,Y,D,ACTION$
6520  LPRINT PT TAB(10) X TAB(20) Y TAB(30) D TAB(42) ACTION$
6530  NEXT I
6540  LPRINT CHR$(12)
6550  GOTO 6470
6560  LPRINT CHR$(12)
6570  CLOSE #1: RETURN
6580  CLEAR: GOTO 30

7000  CLS: LOCATE 10,33: PRINT "SESSION ENDED": END
```