Session 3
Paper (d)

PLANNING FOR LOGGING AND TRANSPORTATION

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INTRODUCTION

The first step in harvesting trees is the planning process. Harvesting plans are most effective if they involve :

- large area planning (block or drainage system) followed by specific logging unit planning
- integration of transportation planning and logging planning
- whole system consideration and component interactions.

This type of planning provides a flexible framework to guide roading and harvesting operations over a relatively long period. Strategic management decisions can be aided by having this type of information available. Also, negative site impacts can be minimised while at the same time maintaining a high profit level because the individual components of the whole system fit together in the planning structure.

The type of harvest planning outlined above is even more important on portions of the future new crop forests currently growing on steep slopes with sensitive soil and slope conditions. Past harvest planning and operational practices seen on the gentle terrain of the Central North Island will not be appropriate in these future areas. In addition, future second crop harvesting operations on gentle terrain can benefit from this level of planning because of the importance of new issues.

Harvest planning involves the following skills :

- ability to identify appropriate harvesting systems that meet specific objectives and constraints. Analytical techniques, such as deflection analysis with cable systems, are required to evaluate system feasibility.

- ability to select an "optimum system" between alternative feasible harvesting systems. This involves considerations, for example, of road and landing space, minimising total cost concept, break-even analysis and alternative transportation networks. There is a variety of computer software available to aid these sorts of considerations.

- ability to assemble the appropriate information and utilise it in an effective decision-making framework to carry out the planning process.

The importance of harvest planning and the development of necessary skills for effective planning is recognised in research, extension and teaching programs at LIRA, the FRI and the University of Canterbury. Other parts of the New Zealand forest industry however have not always practiced large area planning with an emphasis on integrating transportation and logging objectives and constraints (there are some exceptions). In addition, little use has been made of analytical planning tools such as deflection analysis and network analysis.

The purpose therefore of this report is to demonstrate the benefits and methods of such planning by completing a case study harvest plan for a representative area.

The concepts emphasised are :

- Whole system; total cost approach.

- Planning the logging and transportation system together.

- Planning tools (software) :

    - cable layout and analysis
    - skidder/crawler tractor productivity/costs
    - spreadsheets - units costs
        - average haul distance
    - machine costing
    - network analysis.

PLANNING AREA

The Tairau Forest, Forestry Corporation of New Zealand, was selected as a representative forest where the logging and transportation planning can be demonstrated.

This forest is an example of an area that is currently entering a new Forest Corporation structure with emphasis on commercial accountability. In addition, there is an overlying importance of environmental concerns associated with surrounding farm land and recreational use of the resources.

The Tairua Forest is generally isolated from other exotic forest blocks. Logs from the forest are transported in three directions, either north, south or west; sawlogs travel to Waihi, Te Puke, Auckland or Kopu; and pulpwood to either Kinleith or Kawerau. Logging operations are generally conducted throughout the year rather than on a seasonal basis.

The forest is characterised as an old exotic forest with a diversity of tree species. Past and current logging focuses on the earlier plantings (e.g. 1938 - 1942). There are remnant stands scattered through the forest that were passed over originally as being non-loggable. Future trends are towards younger age classes and a smaller piece size that will be common in other new or second crop forests.

Other characteristics of the forest that influence harvest planning include the following :

- Topography is broken with short, steep slopes (greater than 50% or 25°).

- Clay soils are generally present that are highly water sensitive.

- There is reasonable access to adequate aggregate material for roads and landings.

- The general roading pattern is in place, however future considerations are needed regarding :

  * cases for variations in road alignment or grade
  * putting roads to bed versus maintenance
  * spur roads
  * main road placement in some large blocks
  * decisions regarding the direction of cartage from logging sites to alternative main transportation routes (Forest Corporation main roads, County or State roads)

- Current logging systems are a mix of cable yarding and ground skidding :

  * Madill 071, mainly North Bend
  * Madill 009, mainly Highlead or Scab Skyline
  * Smallwood hauler
  * Clark C8 skidder
  * Other skidders and tractors with cable operations.

Log fleeting and loading is generally carried out with a front end loader on medium to large-size landings. Whole trees are yarded to the landing where crosscutting is completed. Multiple log sorts by species and product type range from approximately three to five sorts.

HARVEST PLANS

Compartments 130 and 131 were selected for the example case study reported here. The existing plan for this area was compared with an alternate plan (Figures 1 and 2).

In the existing plan, trees were hauled downhill off a steep slope and across a draw to the road. A Madill 009 used both high-lead and the scab skyline system. A skidder and tractor were used for hauling logs down gentle slopes to the main road. A road was constructed "on top" of the area to log the remaining portion with ground based equipment (mainly uphill hauling).

In the alternate plan, skidder hauling to the main road was planned, similar to the existing plan. The main difference was the layout for logging the short steep section above the draw. A road was located along the break in slope. The Madill 071 mobile hauler with a hydraulic loader would be used for logging the steep section. Small landings or continuous roadside landings would be used along with a tractor as a mobile tailhold. On the gentle terrain, logs would be dragged downhill with a skidder.

How can the planning software be utilised to evaluate these two plans and develop total harvesting cost for a comparison?

HARVEST PLANNING ANALYSIS

EXAMPLE USE OF CABLE ANALYSIS PROGRAM

In the alternate plan, is it feasible to haul logs over the terrain with a landing at the end of the spur road, or does the road need to be extended down to the break in slope? Logger PC was used for evaluating the payload capability of the skyline system. Required input and the analysis output are shown in Figures 3 - 7. Information is in imperial units, however metric units could also be used. The results show that the spur road should be extended down to the break with a landing around "TP 5". There is inadequate deflection for sufficient loads with the landing at "TP 1" when using the Madill 071. Payloads are improved with a larger tower (TY 90) at TP 1.

EXAMPLE USE OF SKIDDER ANALYSIS PROGRAM

Skid PC was used to determine production rates and costs for all ground skidding settings in both plans. Example input requirements and output for setting 4A in the alternate plan is shown in Figures 8 and 9. For this program, imperial units are required, unless the program is modified.

EXAMPLE USE OF A SPREADSHEET PROGRAM FOR COSTS

Spreadsheet programs can be set up in any format appropriate to the user's needs (available input and desired output). Two example programs were used in this case study for estimating production and cost.

Firstly, hauler costs were calculated from information about each setting, hauler set up time and cycle times. Spreadsheet input and output are shown for the existing plan, setting 3B, and the alternate plan, setting 6, in Figures 10 and 11. It is easy to complete sensitivity analysis on input variables to evaluate their importance. Example sensitivity graphs are shown for hook time, delay time, inhaul speed, volume/drag, hauling distance and gang cost; Figures 12 - 14.

Secondly, average hauling distance was determined based on setting co-ordinates. Example co-ordinate inputs and output are shown in Figure 15 for setting 4A - alternate plan, and setting 3B - existing plan.

EXAMPLE USE OF A MACHINE COSTING AND TOTAL COST PROGRAM

The PACE program was used for calculating machine ownership and operating costs. Example input and output are shown in Figures 16 - 19 for a hydraulic knuckleboom loader.

The PACE program can also be used for developing total cost from individual machine cost and production data. A general example, not related to this case study, is shown in Figure 20.

TOTAL COST COMPARISON

Assumptions and a cost comparison between the existing plan and alternate plan are shown below :

ASSUMPTIONS :

Area, 80 hectares
Radiata Pine, 30 yrs
250 Stems/Hectare
Mean dbh = 55 cm
Tree Size = 2.5 m3
Volume/Hectare = 625 m3

	EXISTING	ALTERNATE	DIFFERENCE	
LOGGING SYSTEMS				
Skidder	34,393 m3 $6.08/m3	32,819 m3 $4.99/m3		
Cable	15,762 m3	17,336 m3		
Logs	$23.11/m3	$15.30/m3		
Trees	$16.46/m3	-		
LANDINGS	6 landings $0.44/m3	4 landings $0.24/m3		
ROADS	1.35 km $0.74/m3	1.70 km $0.86/m3		
TOTAL COST				
Logs	$632,552	$484,178	$148,374	23%
Trees	$527,735	-	$43,557	8%

The total cost comparison shows that the alternate plan had a lower cost by 8% or 23%, depending on the log preparation assumption. A similar portion of wood was hauled by skidder and hauler in both plans. In the alternate plan, the "upper" spur road was layed out such that ground skidding was downhill and a mobile hauler could be used for uphill hauling the steep slope. Line shifts and machine moves were comparatively fast with a layout that made it feasible to use a mobile tailhold. There were also fewer landings and the landing size was smaller in the alternate plan. Road length was slightly longer in the alternate plan.

CONCLUSION

This case study has shown how various computer software can be utilised in harvest planning. The software is not a substitute for the necessary field planning and layout. Also, the information provided is only as good as the input by the user.

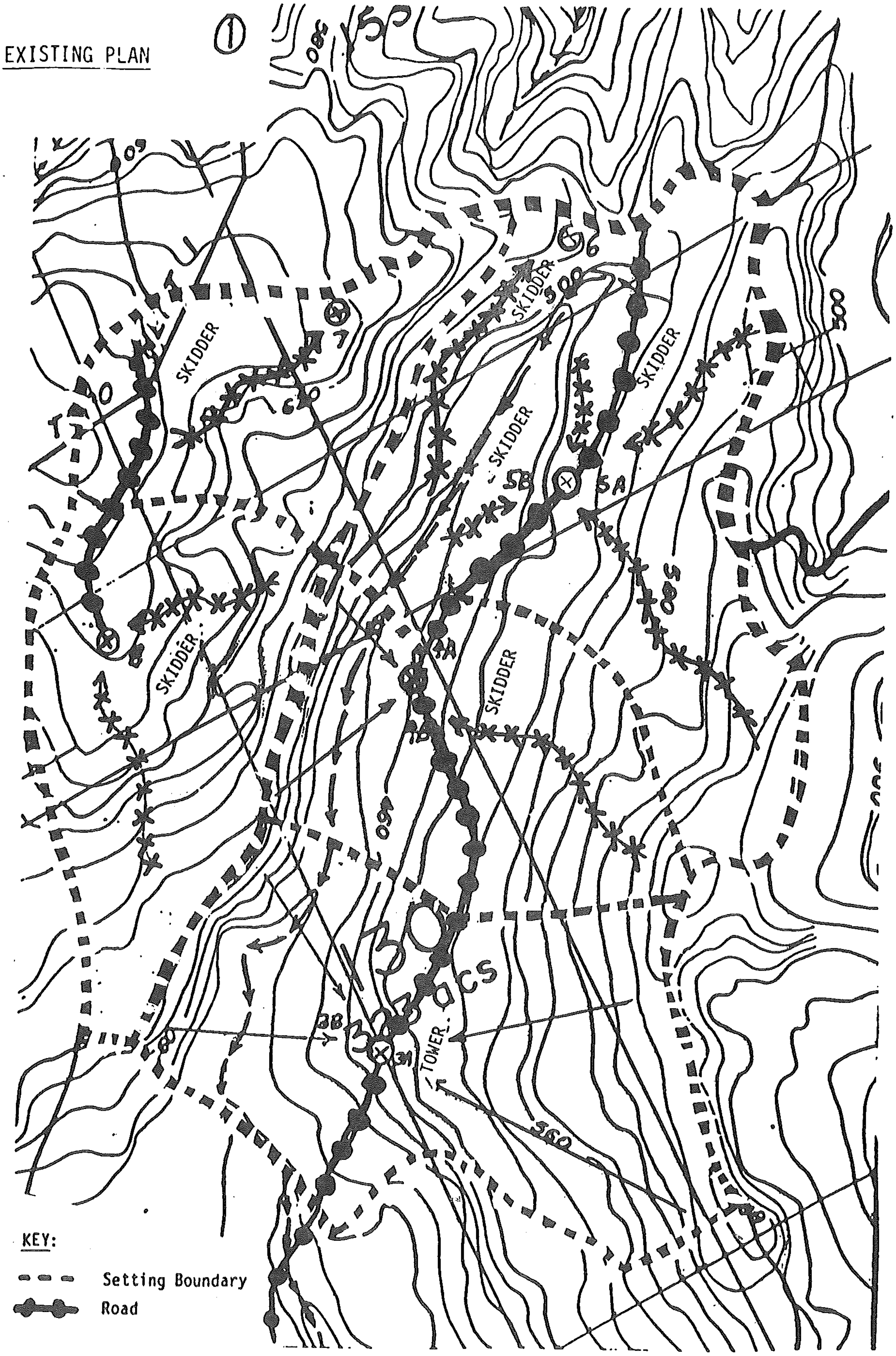
These planning tools do assist in the technical evaluation of road and logging planning. They also have the benefit of speeding up much of the tedious work load such as routine calculations of setting area, average haul distance or costing. Thus it is feasible to have more time for field planning or to obtain feedback during the harvest operation.

The case study shows a comparison of two harvest plans for a small area on a total cost basis. This concept should be applied to large area operational planning. The absolute numbers in this example are not critical. The same assumptions were used in both plans for a relative comparison.

In the alternate plan, road layout and logging systems were considered together. The roads were located not only for a transportation objective; they were also located to achieve the best logging results.

The whole system approach can actually be expanded beyond the elements considered in this example to include more parts of forest management. The aim is not to consider individual components separately, rather to consider them jointly with their interactions, to obtain the overall best management plan.

EXISTING PLAN



KEY:

Setting Boundary

Road

Tower or Skidder Setting

Figure 1

ALTERNATE PLAN

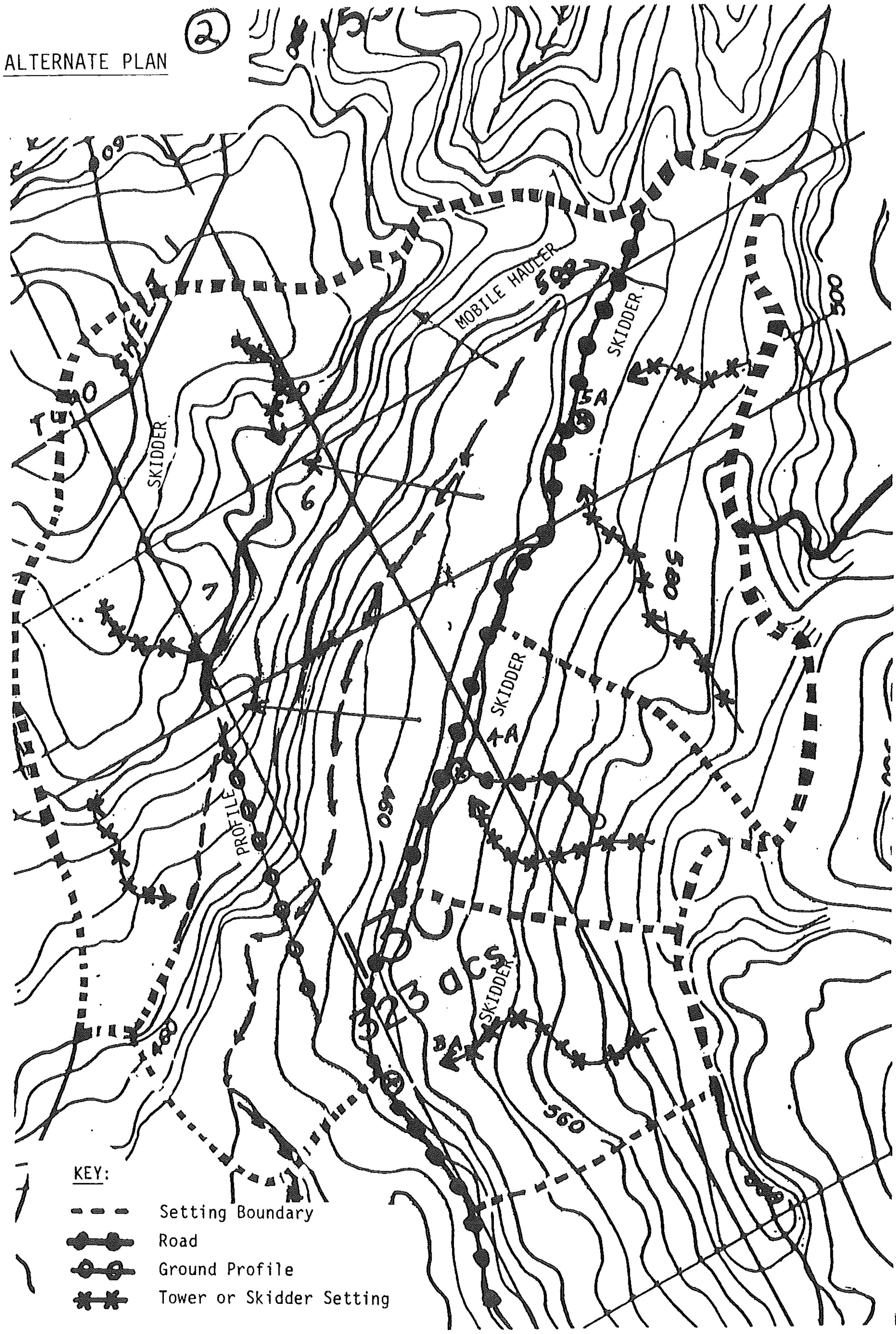
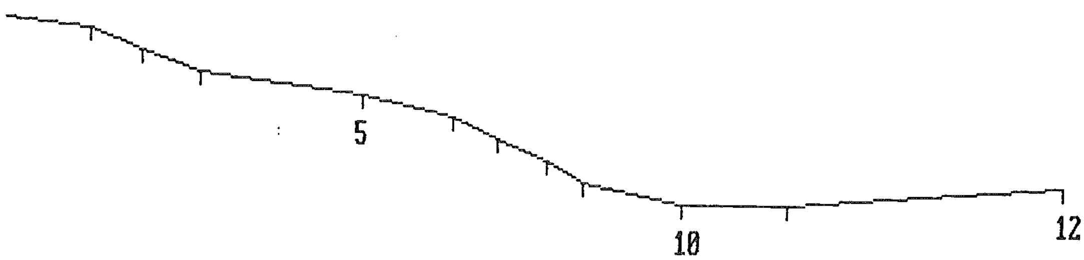


Figure 2

PROFILE : SEMINAR .PRO
SCALE: 100 ft



CREATING a PROFILE:

T.P.#	X COORD	Y COORD	SLOPE DIST	% SLOPE
1	0	590	99	-10
2	98	580	62	-34
3	157	560	69	-30
4	223	540	185	-11
5	407	520	103	-20
6	508	500	54	-40
7	558	480	59	-36
8	613	460	47	-47
9	656	440	114	-18
10	768	420	118	0
11	886	420	309	6
12	1194	440		

Figure 3 - Ground Profile for Setting 6

HAULER/CARRIAGE INFORMATION...TAIRUA MADILL 071

SPAR HEIGHT (FT)............. 49
CARRIAGE WEIGHT (LB)......... 1000

	DIAMETER (IN)	WEIGHT (LB/FT)	SWL (LBS)	LENGTH (FT)
SKYLINE.........	1	1.85	30000	1900
MAINLINE........	3/4	1.04	17100	2100
HAULBACK........	5/8	0.72	12000	4400
SLACKPULLING....	3/8	0.26	4370	3300

HAULER/CARRIAGE INFORMATION...THUNDERBIRD TY90

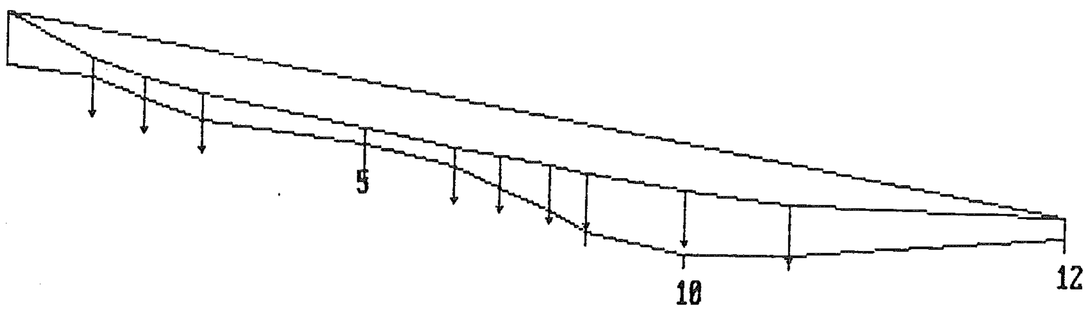
SPAR HEIGHT (FT)............. 90
CARRIAGE WEIGHT (LB)......... 1800

	DIAMETER (IN)	WEIGHT (LB/FT)	SWL (LBS)	LENGTH (FT)
SKYLINE.........	1 1/4	2.89	46300	2500
MAINLINE........	7/8	1.42	23100	3100
HAULBACK........	3/4	1.04	17100	6100
SLACKPULLING....	0	0.00	0	0

Figure 4 - Hauler File Data

PROFILE : SEMINAR .PRO
SCALE: 100 ft

LANDING at TP1



LANDING at TP5

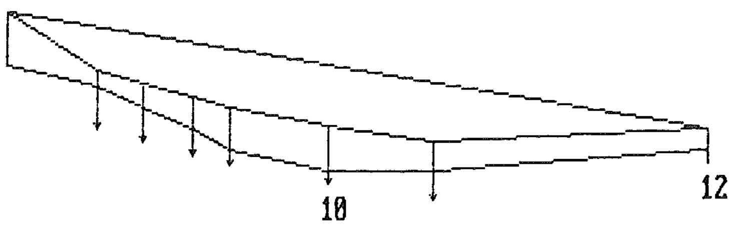


Figure 5 - Skyline Loadpath

LIVE SKYLINE LOAD ANALYSIS

ELLIPTICAL LOADPATH ANALYSIS

PROFILE: SEMINAR .PRO   YARDER: TAIRUA .YRD

HEADSPAR HT	= 49	TAILSPAR HT	= 20
LANDING CUT(-)/FILL(+)	= 0	YARDING TOWARDS YARDER	
CARRIAGE CLEARANCE	= 15	LOG DRAG COMPUTED	
LOG LENGTH	= 40	CHOKER LENGTH	= 14

RIGGING LENGTH REQUIREMENTS	REQUIRED	AVAILABLE
SKYLINE	1376	1900
MAINLINE	1007	2100
HAULBACK	2574	4400

LANDING at TP1

TERRAIN POINT	PAYLOAD	LIMITING LINE	REQUIRED LINE	CARRIAGE CLEARANCE	LOG CLEARANCE	TYPE SUSPENSION
2	14544	SKYLINE	MAINLINE	15.0	5.0	PARTIAL
3	9808	SKYLINE	MAINLINE	19.7	9.0	PARTIAL
4	8283	SKYLINE	MAINLINE	24.6	12.4	PARTIAL
5	4524	SKYLINE	MAINLINE	15.0	4.3	PARTIAL
6	3234	SKYLINE	MAINLINE	18.1	8.0	PARTIAL
7	2789	SKYLINE	MAINLINE	30.2	18.7	PARTIAL
8	2300	SKYLINE	MAINLINE	42.0	29.4	PARTIAL
9	1945	SKYLINE	MAINLINE	55.8	1.8	TOTAL
10	2040	SKYLINE	MAINLINE	60.7	6.7	TOTAL
11	3595	SKYLINE	MAINLINE	46.9	33.0	PARTIAL

1 ton

< * = Critical pt >

LANDING at TP5

TERRAIN POINT	PAYLOAD	LIMITING LINE	REQUIRED LINE	CARRIAGE CLEARANCE	LOG CLEARANCE	TYPE SUSPENSION
6	23107	SKYLINE	MAINLINE	15.0	5.3	PARTIAL
7	16300	SKYLINE	MAINLINE	21.6	10.9	PARTIAL
8	11616	SKYLINE	MAINLINE	28.9	17.8	PARTIAL
9	10951	SKYLINE	MAINLINE	40.2	27.3	PARTIAL
10	10872	SKYLINE	MAINLINE	41.3	27.8	PARTIAL
11	13606	SKYLINE	MAINLINE	26.4	13.1	PARTIAL

5 ton

< * = Critical pt >

Figure 6 - Payload Analysis Output for Madill 071

LANDING at T.P.I

TERRAIN POINT		PAYLOAD	LIMITING LINE	REQUIRED LINE	CARRIAGE CLEARANCE	LOG CLEARANCE	TYPE SUSPENSION
2		34012	MAINLINE	MAINLINE	20.0	2.8	PARTIAL
3		37036	MAINLINE	MAINLINE	20.0	2.5	PARTIAL
4		44548	MAINLINE	MAINLINE	20.0	0.4	PARTIAL
5		16867	SKYLINE	MAINLINE	20.0	1.5	PARTIAL
6		12461	SKYLINE	MAINLINE	20.0	3.3	PARTIAL
7		10937	SKYLINE	MAINLINE	30.7	11.5	PARTIAL
8	4tons	9099	SKYLINE	MAINLINE	41.0	20.5	PARTIAL
9		9259	SKYLINE	MAINLINE	53.9	30.5	PARTIAL
10		10480	SKYLINE	MAINLINE	57.1	32.6	PARTIAL
11		15071	SKYLINE	MAINLINE	42.4	18.3	PARTIAL

< * = Critical pt >

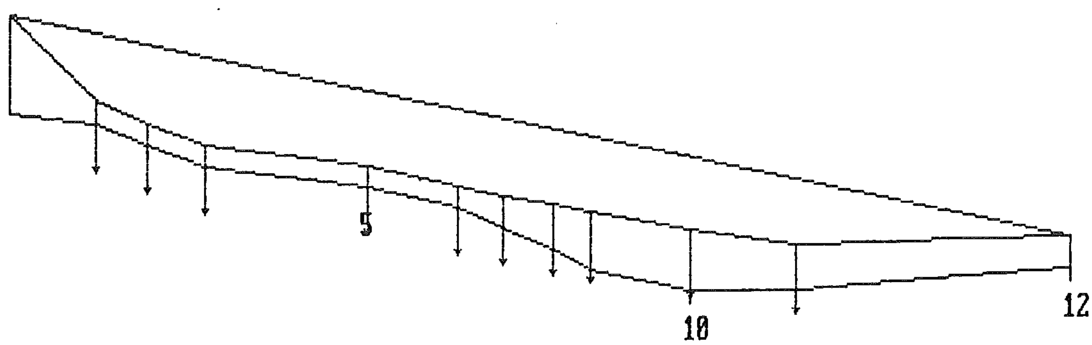


Figure 7 - Payload Analysis and Loadpath for TY 90 Tower

- Skid Path Conditions

SETTING 4A

SEGMENT	SLOPE %	DISTANCE ft	CONE INDEX p.s.i.
1	-12	165	80
2	-15	133	80
3	-20	301	80

- SELECT a SKIDDER or CRAWLER TRACTOR

SELECT SKIDDER

1) CLARK 664C (91 hp)
2) CLARK 667C (126 hp)
3) CLARK 880 (267 hp)
4) CAT 518 (120 hp)
5) CAT 528 (175 hp)
6) JOHN DEERE 440 (70 hp)
7) JOHN DEERE 540 (90 hp)
8) JOHN DEERE 640 (110 hp)
9) User specified skidder

- OPERATING CONDITIONS

Figure 8 - Input Requirements for SKID PC

TAIRUA ALT 4A

----------------------------------< SEGMENT 2 >----------------------------

SLOPE = -15 % DISTANCE = 133 ft CONE INDEX = 80 psi

LOAD FRONT TIRES (axle) = 17519 lbs LOAD REAR TIRES (axle) = 22230 lbs

LOG WEIGHT ON GROUND = 6929 lbs
LOG RESISTANCE = 1710 lbs
WINCH LINE TENSION = 9575 lbs

VELOCITY LOADED = 12.03 mph VELOCITY UNLOADED = 4.32 mph

LOADED REAR TIRE SINKAGE = 1.42 INCHES
UNLOADED REAR TIRE SINKAGE = 0.74 INCHES
SLIP LOADED = 10.00 %
SLIP UNLOADED = 10.00 %
REAR TIRE INFLATION MINIMUM = 23.57 PSI
FRONT TIRE INFLATION MINIMUM = 18.57 PSI

------------------------------< PRODUCTION SUMMARY >--------------------------

TITLE: TAIRUA ALT 4A

SKIDDER: CAT 528

PAYLOAD: 16500 lbs 7.5 tons

TOTAL ROUND TRIP TURN TIME = 6.79 MINUTES (DELAY FREE)

PRODUCTIVITY (WITH DELAYS) = 13.13 MBF/HOUR 59m³/hr
= 21.18 CUNITS PER HOUR

UNIT COST (WITH DELAYS) = 22.16 $/MBF $4.91/m³
= 13.74 $/CUNIT

Figure 9 - SKID PC Output

```
     !  A  !!  B  !!  C  !!  D  !!  E  !!  F  !!  G  !
1                 HAULER COSTS                         0
2                 ------------
3    TITLE:   TOWER EXISTING PLAN 3B
4
5    Volume in block                  #        4985   m3
6    Average Yarding Distance         #         150   m
7    Machine costs (incl labour)*     $         491   $/hr
8    Move in time                     #           4   hours
9    Volume per cycle*                #           5   m3
10   Outhaul velocity                 #         300   m/min
11   Hook time*                       #         1.5   min
12   Inhaul velocity                  #         100   m/min
13   Unhook time*                     #          .4   min
14   Delay                            #        15.6   min/hour
15   Other cycle times                          1.7   min/cycle
16   Line shift                       #         7.5   min/hour
17                                       -------------
18   COST per m3                         $    15.30
19                                       -------------
20   Cycle time (incl Other cycle times)       5.60   Minutes
21   Production rate                          32.95   m3/hr
```

```
SuperCalc ver.  2.00

F18 $      = ((((F6/F10)+(F6/F12)+F11+F13+F15)*F7/60)/F9)*(60/(60-F14-F16))+(F8*F
7/F5)
F19        = "-------------
F20 $      = (F6/F10)+(F6/F12)+F11+F13+F15
F21 $      = (F9/(F20/60))*((60-F14-F16)/60)
```

$$\text{Cycle time} = \frac{\text{AYD}}{\text{out. velocity}} + \frac{\text{AYD}}{\text{in. velocity}} + \text{hook time} + \text{unhook time} + \text{other cycle times}$$

Figure 10 - Spreadsheet Program for Cable Hauling Costs, Setting 3B - Existing Plan

HAULER COSTS

TITLE: TOWER EXISTING PLAN 3B

Volume in block	#	4985	m3
Average Yarding Distance	#	150	m
Machine costs (incl labour)*	$	491	$/hr
Move in time	#	4	hours
Volume per cycle*	#	5	m3
Outhaul velocity	#	300	m/min
Hook time*	#	3.5	min
Inhaul velocity	#	100	m/min
Unhook time*	#	.9	min
Delay	#	15.6	min/hour
Other cycle times		1.7	min/cycle
Line shift	#	7.5	min/hour
COST per m3		$ 21.95	
Cycle time (incl Other cycle times)		8.10	Minutes
Production rate		22.78	m3/hr

HAULER COSTS

TITLE: MOBILE YARDER ALT 6

Volume in block	#	17336	m3
Average Yarding Distance	#	125	m
Machine costs (incl labour)*	$	407	$/hr
Move in time	#	3	hours
Volume per cycle*	#	4	m3
Outhaul velocity	#	400	m/min
Hook time*	#	2.8	min
Inhaul velocity	#	150	m/min
Unhook time*	#	.7	min
Delay	#	13.1	min/hour
Other cycle times		1.7	min/cycle
Line shift	#	4.5	min/hour
COST per m3		$ 15.30	
Cycle time (incl Other cycle times)		6.35	Minutes
Production rate		26.73	m3/hr

Figure 11 - Spreadsheet Data for Cable Hauling Costs, Setting 3B - Existing Plan and Setting 6 - Alternate Plan

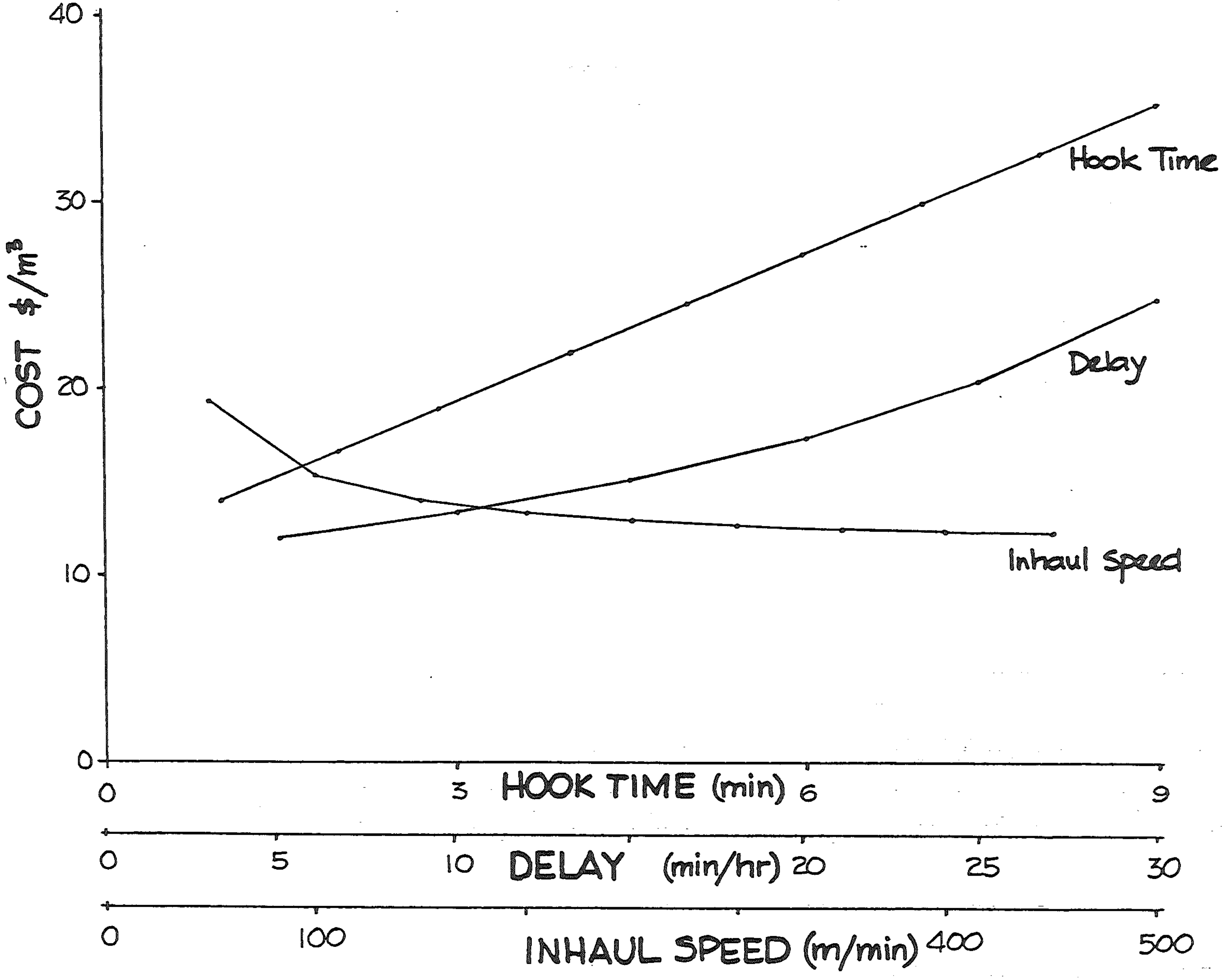


Figure 12 - Sensitivity Analysis

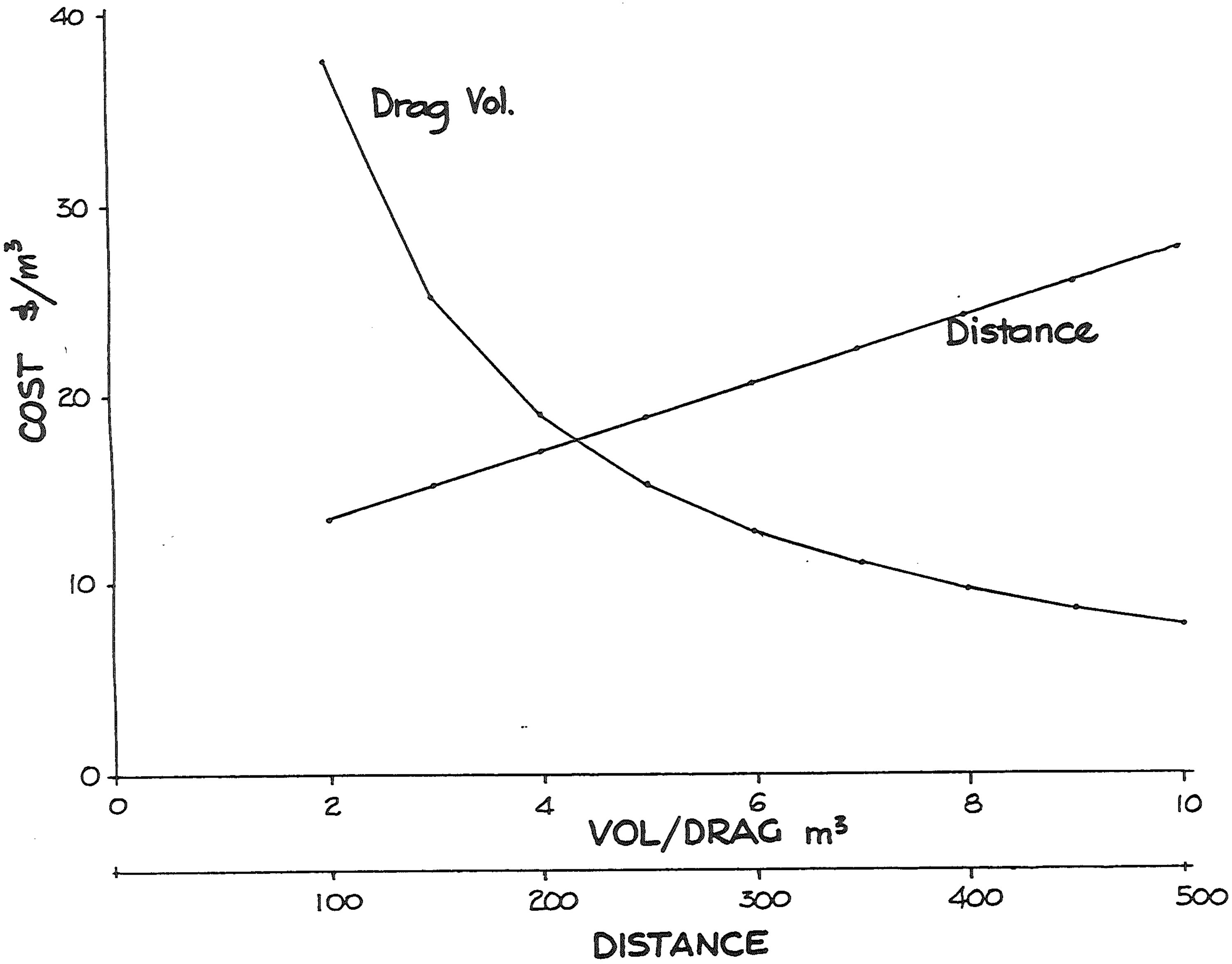


Figure 13 - Sensitivity Analysis

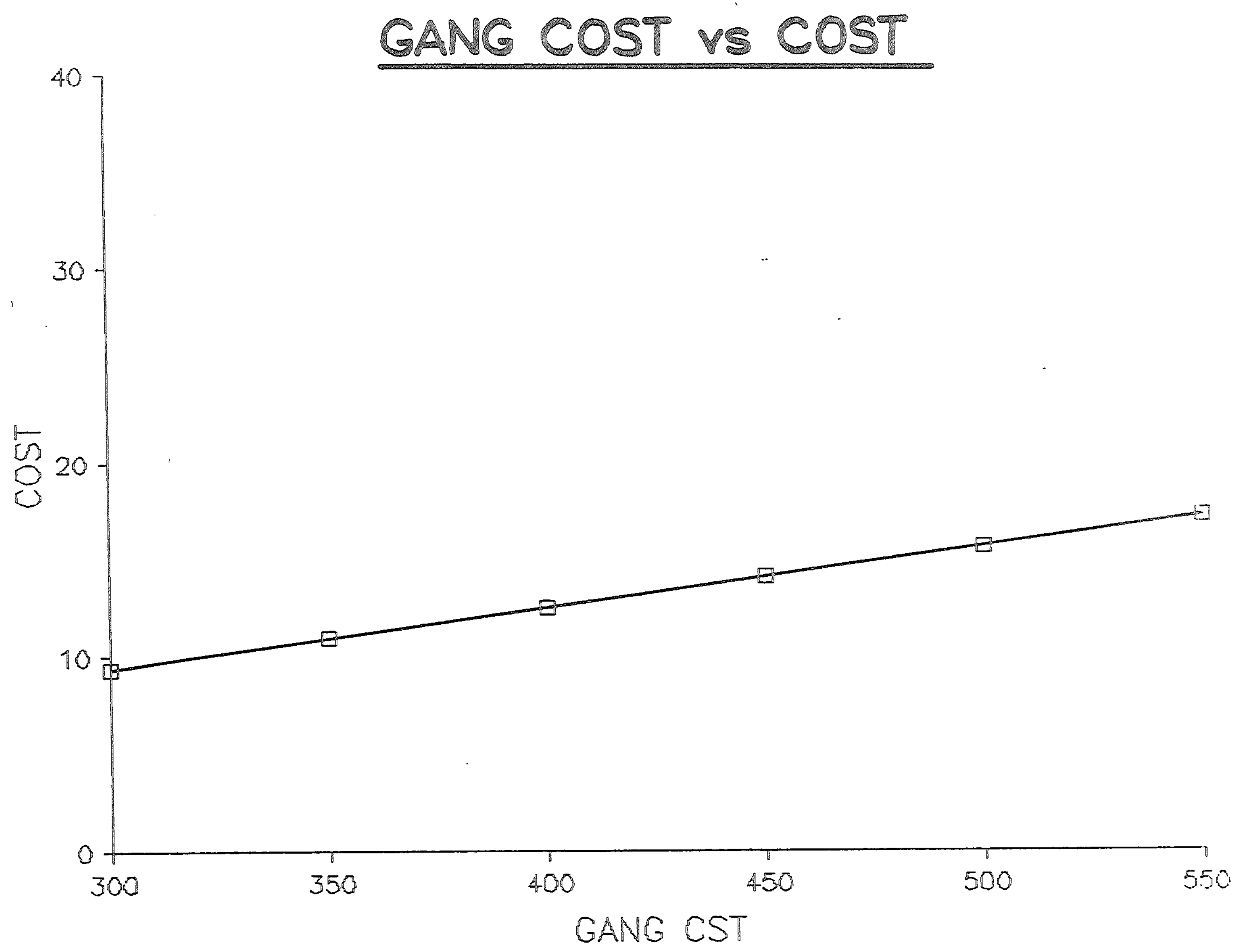


Figure 14 - Sensitivity Analysis

AVERAGE SKIDDING DISTANCE

SETTING COORDINATES
(Landing at 0,0)
(Finish at 0,0)

NAME: TAIRUA
SETTING 4A

			ASD (M)	AREA (HA)
1	0	0		
2	10	-10		
3	130	85		
4	-25	235		
5	-210	310		
6	-180	250		
7	-260	180		
8	-190	20		
9	-105	-110		
10	10	-10		
11	0	0	160.2	8.3
12	0	0		

AVERAGE SKIDDING DISTANCE

SETTING COORDINATES
(Landing at 0,0)
(Finish at 0,0)

NAME: TAIRUA
SETTING 3B

			ASD (M)	AREA (HA)
1	0	0		
2	90	140		
3	290	0		
4	140	-250		
5	25	-200		
6	-120	-150		
7	0	0	149.6	8.1
8	0	0		

Figure 15 - Spreadsheet Program for Average Hauling Distance

Machine Costing Example - Hydraulic Knuckleboom Loader

Equipment Ownership Costs

->Delivered equipment cost	$	280,000.00
Minus line and rigging cost	$	0.00
Minus tire or track replacement cost	$	0.00
Minus residual (salvage) value	$	56,000.00
Life of equipment (Years)	#	7.00
Number of days worked per year	#	230.00
Number of hours worked per day	#	6.50
Interest Expense	%	21.00
Percent of average annual investment for: Taxes, License, Insurance, and Storage	%	5.50
Depreciable value:	$	224,000.00
Equipment depreciation:	$	32,000.00
Average annual investment:	$	184,000.00
Interest expense:	$	38,640.00
Taxes, license, insurance and storage:	$	10,120.00
Annual ownership cost:	$	80,760.00
Annual utilization (Hours per year):	#	1,495.00
Ownership cost (Dollars per hour):	$	54.02 ←

Current value = 280,000.00

[ESC]=Menu (Highlight value to change and press return)

Figure 16

Equipment Operating Costs

Percent of equipment depreciation for repairs	%	80.00
Fuel amount (Liters per hour)	#	15.00
Fuel cost (Per liter)	$	0.63
Percent of fuel consumption for lubricants	%	10.00
Cost of oil and lubricants (Per liter)	$	2.14
Cost of lines	$	0.00
Estimated life of lines (Hours)	#	0.00
Cost of rigging	$	0.00
Estimated life of rigging (Hours)	#	0.00
Cost of tires or tracks	$	0.00
->Estimated life of tires or tracks (Hours)	#	0.00
Repairs and maintenance:	$	17.12
Fuel:	$	9.45
Oil and lubricants:	$	3.21
Lines:	$	0.00
Rigging:	$	0.00
Tires or tracks:	$	0.00
Equipment operating cost (Subtotal):	$	29.78 ←

Current value = 0.00

[ESC]=Menu (Highlight value to change and press return)

Figure 17

```
IMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM5 Labor Costs FMMMMMMMMMMMMMMMMMMMMMMMMMI
:
:->Base wage for 1st crew position  (Per hour)      $          11.50
:  Base wage for 2nd crew position  (Per hour)      $           0.00
:  Base wage for 3rd crew position  (Per hour)      $           0.00
:  Base wage for 4th crew position  (Per hour)      $           0.00
:  Base wage for 5th crew position  (Per hour)      $           0.00
:  Base wage for 6th crew position  (Per hour)      $           0.00
:  Fringe benefits                                  %          31.00
:  Travel time per day (Hours)                      #           1.50
:  Operating time per day (Hours)                   #           8.00
:  Percent of direct labor cost for supervision     %          10.00
:
GDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
:
:  Total number of workers:                         #           1.00
:  Total crew wage (Per hour):                      $          11.50
:  Direct labor cost:                               $          17.89
:  Supervision and overhead:                        $           1.79
:  Labor cost (Subtotal):                           $          19.68 <--
:  Total operating cost (Operating+Labor):          $          49.46 <--
:
HMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
                          Current value =        11.50
[ESC]=Menu       (Highlight value to change and press return)
```

Figure 18

```
----------------------------------- Summary ---------------------------------
                      *** HYDRAULIC KNUCKLEBOOM LOADER ***
Ownership
    Depreciable value:                               $    224,000.00
    Equipment depreciation:                          $     32,000.00 / Year
    Interest expense:                                $     38,640.00 / Year
    Taxes, license, insurance and storage:           $     10,120.00 / Year
    Annual ownership cost:                           $     80,760.00 / Year
    Ownership cost (Subtotal):                       $         54.02 / Hour <--
Machine operating
    Repairs and maintenance:                         $         17.12 / Hour
    Fuel and oil:                                    $         12.66 / Hour
    Lines and rigging:                               $          0.00 / Hour
    Tires or tracks:                                 $          0.00 / Hour
    Equipment operating cost  (Subtotal):            $         29.78 / Hour <--
Labor
    Direct labor cost:                               $         17.89 / Hour
    Supervision and overhead:                        $          1.79 / Hour
    Labor cost (Subtotal):                           $         19.68 / Hour <--

OWNERSHIP COST                                       $         54.02 / Hour
OPERATING COST                                       $         29.78 / Hour
LABOR COST                                           $         19.68 / Hour
Machine rate (Ownership + Operating + Labor)         $        103.48 / Hour <--
                      *** Press [RETURN] for the menu ***
```

Figure 19

```
 LMMM5 Skidding/Yarding FMMMMMMM9  Loading  LMMMMMMMM;
:                                                                        :
: Machine Cost (Skidder.Mac):                  $       220.00   $/hr     :
: Move-in time:                                #         0.50   hr       :
: Volume per cycle:                            #         7.00   m3       :
: Outhaul velocity (empty):                    #       300.00   m/min    :
: Lateral outhaul velocity (empty):            #         0.00   m/min    :
: Hook time:                                   #         5.00   min      :
: Lateral inhaul velocity (loaded):            #         0.00   m/min    :
: Inhaul velocity (loaded):                    #       100.00   m/min    :
: Unhook time:                                 #         1.00   min      :
: Delay (time per hour):                       #        10.00   min/hr   :
:                                                                        :
HMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM<
SUMMARY:
```

	Production (m3/hr)	Ownership ($/m3)	Operating ($/m3)	Labor ($/m3)	Total Cost ($/m3)
FALL	# 12.50	$ 0.08	$ 0.31	$ 1.65	$ 2.04
SKID	# 30.15	$ 2.32	$ 2.60	$ 2.38	$ 7.30
LOAD	# 71.43	$ 0.33	$ 0.29	$ 0.36	$ 0.98
TRAN	# 7.33	$ 2.15	$ 2.82	$ 2.71	$ 7.68
ROAD		$ 0.63	$ 0.58	$ 0.39	$ 1.60
Totals		$ 5.51	$ 6.60	$ 7.48	$ 19.60

Figure 20 - Total Cost Example