SKYLINE ANALYSIS PROGRAMS FOR USE WITH EXTENDED MEMORY PROGRAMMABLE CALCULATORS

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ABSTRACT

This paper describes a mathematical formulation and computer programs for use on hand-held programmable calculators to analyze the load carrying capacity of skyline systems, including the effects of log drag. The actual physical characteristics of the load and the ground geometry are used in the analysis of the payload capacities for standing, live, and running skylines. Included in this paper are instructions for the use of the programs and example problems illustrating their use.

LEGEND OF TERMS

A = choker angle during partial log suspension (measured from vertical)

μ = coefficient of friction

$\emptyset$ = choker angle when log in complete contact with ground (measured from horizontal)

Θ = intermediate term in elliptical load path calculation

B = log-to-ground angle

CG = fraction of log length from dragging end to center of gravity $(\frac{L_4}{L_3})$

C_L = carriage clearance; the vertical distance from the ground to the load analysis point on the skyline

d_1 = horizontal distance from yarder to load point

d_2 = horizontal distance from tail hold to load point

E = vertical distance from headspar top to cable attachment point on tailspar

$E_D = \frac{L_2}{L_2 - L_4}$ which is also $\frac{(TP)}{(TP) - (CG)}$

H_A = horizontal tension component in skyline segment A

H_B = horizontal tension component in skyline segment B

H_M = horizontal tension component in mainline

H_4 = horizontal tension component in haulback

H/W = ratio of horizontal component of choker tension to load weight

h_1 = vertical distance from headspar top to load point

h_2 = vertical distance from point of cable attachment on tailspar to load point

L = horizontal distance from headspar to tailspar

L_1 = choker length

W = log load weight

W_1 = skyline weight per foot

W_3 = mainline weight per foot

W_4 = haulback weight per foot

X = length of skyline segment A in elliptical load path calculation

Y = length of skyline segment B in elliptical load path calculation

INTRODUCTION

Planning for skyline logging systems requires that the payload capability for these systems be adequate to meet the minimum payload requirements for the area being studied. Several methods are available for determining the payload capability of skylines, including graphical payload analysis, chain and board model simulation of a skyline (Binkley, Sessions 1980), and direct payload calculation methods which use rigid link or catenary formulations.

Catenary solutions most accurately predict forces in cable tension problems, however, rigid link approximations yield results very near the catenary solution when cable tensions are near their safe working tension (Carson 1976), and do so directly and quickly. Most computer programs developed to analyze skyline payloads use the rigid link model because of the less cumbersome mathematics involved. All of the programs referred to in this paper use rigid link or rigid link based methods of determining cable tensions. Graphical and chain and board techniques have the disadvantages of being less accurate and slower.

This paper presents a set of skyline payload analysis programs for use on relatively inexpensive and commonly available extended memory hand-held calculators. These programs take advantage of the extended memory of the newer calculators to consolidate several previously available programs and to simplify the skill and effort needed for use.

OBJECTIVES

The purpose of this study is to develop a set of skyline analysis programs for use on handheld programmable calculators with extended memory capability. The intent of this project is to: a) consolidate several skyline programs which are already available, b) simplify the effort required of the user to operate the programs, c) reduce the time required to perform routine payload analysis, d) provide the user with a more "friendly" program to interact with, and e) eliminate as many external adjustments required in the analysis as possible.

The specific objectives of this project are:

1. To provide a set of programs which analyze the load carrying capacity of live, running, and standing skylines for use on an HP-41C calculator.
2. To provide complete user instructions and example problems to illustrate the use of the programs.
3. To present the mathematical formulations and assumptions used in modeling skyline payload capability.
4. To show the magnitude of errors involved in using the estimation formulas for mainline limiting payloads

$$\frac{H}{W} = (\mu\cos S + \sin S)\left(\frac{\cos(S + B)}{E_D(\cos B + \mu\sin B)}\right) \quad (2)$$

(from Carson 1975, PNW-193)

$$A = \tan^{-1}\left(\frac{H}{W}/\frac{V}{W}\right) \quad (3)$$

$$C_L = \frac{L_2 \sin B + L_1 \cos(A + S)}{\cos S} \quad (4)$$

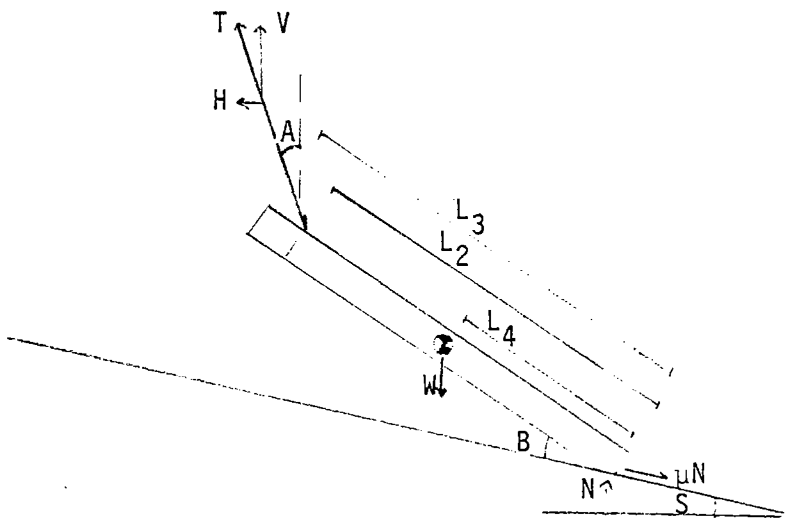


Figure 1. Log Skidding Geometry.

Appendix 3 demonstrates a graphical method for determining these relationships. It should be noted that if the user is analyzing a downhill yarding profile for partial log suspension and slopes equal or exceed the coefficient of friction, the model predicts the log will run ahead of the carriage and cause a negative "A" angle. For downhill slopes this steep, it is recommended to analyze for full suspension.

Log Drag for Standing Skylines

When standing skylines are analyzed, a constant log-to-ground angle can no longer be assumed. Since the length of skyline is fixed during inhaul, the loaded carriage clearance is constantly changing, resulting in varying log-to-ground angles. The carriage clearance at a point can be calculated and will be described later in this report. Solving for the ratios $\frac{V}{W}$ and $\frac{H}{W}$ when the carriage clearance is known requires an iterative procedure that finds the correct combination of choker angle (A) and log-to-ground angle (B) which satisfies force equilibrium and geometric requirements.

Traditionally, the equations used in this procedure have been:

$$B = \sin^{-1}\left(\frac{C_L \cos S - L_1 \cos (A + S)}{L_2}\right) \tag{5}$$

and,

$$A = \tan^{-1} \frac{\frac{\cos S - \sin S \tan B}{E(1 + \mu \tan B)}(\sin S + \mu \cos S)}{1 - \frac{\cos S - \sin B \tan B}{E(1 + \mu \tan B)}(\sin S + \mu \cos S)} \tag{6}$$

The second equation can be further reduced:

$$A = \tan^{-1} \frac{TP - CG}{(CG) \tan (90\text{-}S\text{-}\tan^{-1}\mu) + (TP) \tan (S + B)} \tag{7}$$

This reduced form shortens the calculator time spent in iteration significantly.

Once the angles A and B are known, the equations used to solve $\frac{V}{W}$ and $\frac{H}{W}$ for live skylines can be used. However, since A and B are solved in the iteration procedure, the ratios $\frac{V}{W}$ and $\frac{H}{W}$ can be more simply expressed.

By summing moments about the ground-log contact point, the following relationships can be found:

$$\frac{V}{W} = \frac{(CG) \cos A \cos (B + S)}{(TP) \cos (A + B + S)} \tag{8}$$

$$\frac{H}{W} = \frac{\cos \phi}{\sin \phi + \cos \phi \left(\frac{\cos S - \mu \sin S}{\sin S + \mu \cos S}\right)} \tag{11}$$

where $$\phi = \sin^{-1} \left(\frac{C_L}{L_1} \cos S\right) + S \tag{12}$$

Hang-up situations easily occur when the log is in complete contact with the ground. The model does not take hang-up forces into account. This condition can be avoided by specifying a higher carriage clearance during analysis.

Fully Suspended Load Forces on the Carriage

When loads are fully suspended by either live, running, or standing skyline systems, the force exerted on the carriage is equal to the load weight, plus the choker weight (which is considered negligible) and it all acts vertically. Thus, the ratio $\frac{V}{W} = 1$ and $\frac{H}{W} = 0$.

Carriage Clearance

In this paper, carriage clearance refers to the vertical distance from the skyline at the point where the loaded carriage is positioned to the ground. For live and running skylines, carriage clearance is easily calculated when it is assumed that the skyline will be raised or lowered to maintain a constant log-to-ground angle or a constant carriage clearance. In the case of full log suspension, minimum carriage clearance in the analysis programs is simply,

$$C_L = L_1 + L_2$$

In a skyline payload determination, the highest point on the skyline is assumed to be at the safe working tension (T_u). Knowing that $T_L = T_u - wy$, V_L can be solved using Falk's equation:

$$V_L = \frac{T_L\, y - \frac{1}{2} w d^2}{(d^2 + y^2)^{\frac{1}{2}}} \tag{14}$$

The horizontal force component is:

$$H = \sqrt{T_L{}^2 - V_L{}^2}$$

Traditional rigid link formulations are used to solve for the line tension and vertical force component when the horizontal component is known.

System Geometry

Figure 5 illustrates the model skyline geometry used in the payload analysis programs. The yarder is always on the left.

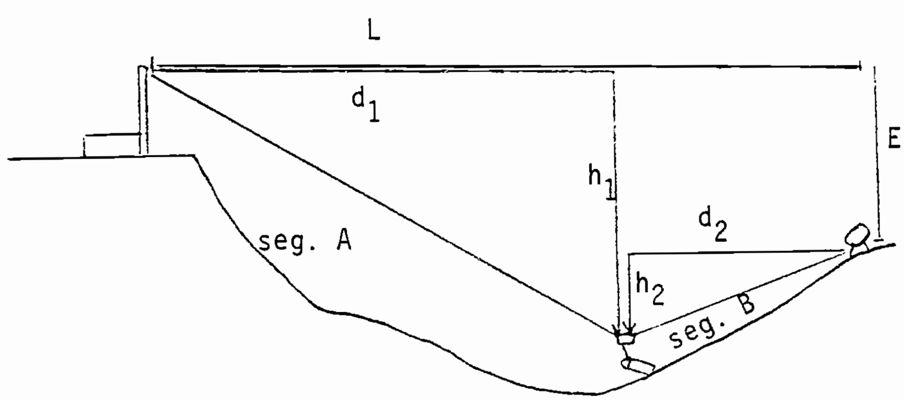


Figure 5. Skyline Geometry Model.

The sign convention for parameters E, h_1, and h_2 is positive as shown in the figure. If E or h_1 is above the horizontal from the top of the headspar, it is negative. If h_2 is above the horizontal from the tail attachment, it is considered negative.

When analyzing with an unclamped carriage, maximum tensions for all lines are considered at the headspar. For a skyline limited payload, the maximum skyline tension at the headspar is the safe working tension of the skyline (SWT SL) when E is positive. When E is negative, the maximum tension allowed at the headspar is (SWT SL) + wE. The same logic applies to the mainline and haulback when analyzing mainline or haulback limiting payloads.

The effect of line stretch on the system geometry is not considered in the programs being presented.

Payload Analysis for Live and Standing Skylines with Unclamped Carriages

The skyline payload analysis programs being presented analyze for clamping and unclamping carriages. Programs "LOAD" and "SSL" analyze unclamped carriages; program "CLCAR" analyzes for a clamped carriage.

The analysis model for an unclamped carriage assumes frictionless sheaves in the carriage and that $T_{LA} = T_{LB}$.

If this term is negative, a model using a haulback rather than a mainline is used.

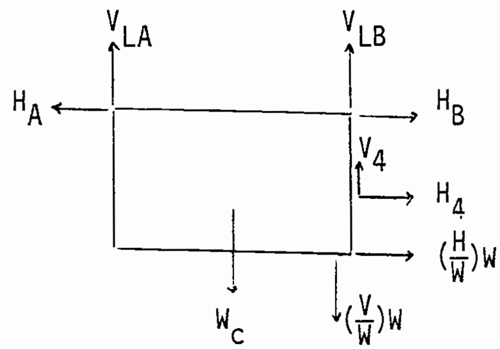


Figure 7. Free Body Diagram of Skyline Limiting Condition Using a Haulback.

The expression for net payload in this case is:

$$W = \frac{V_{LA} + V_{LB} - W_c + (H_A - H_B)\frac{h_2}{d_2} - \frac{W_4\,(h_2^{\,2} + d_2^{\,2})^{\frac{1}{2}}}{2}}{(\frac{V}{W}) + (\frac{H}{W})\frac{h_2}{d_2}} \tag{17}$$

When the skyline limiting payload has been analyzed, mainline tensions can be calculated.

$$V_{LM} = (\frac{V}{W})\,W - V_{LB} - V_{LA} + W_c \tag{18}$$

$$T_M = (V_{LM}^{\,2} + H_M^{\,2})^{\frac{1}{2}} + W_3\,h_1 \tag{19}$$

(Haulback tensions, when used, determined at the carriage.)

If the safe working tension of the mainline (or haulback) is exceeded, the net payload for the system must be recalculated.

In his paper, Tobey developed a direct solution using mainly rigid link analysis to find the net payload capability based on

$$R_{2y} = \left(\frac{V_{LA} + V_{LB}}{H_B - H_A}\right) R_{2x}$$

substituting the definitions of R_{2y} and R_{2x}:

$$\left(\frac{V}{W}\right) W + W_c - V_{LM} = \left(\frac{V_{LA} + V_{LB}}{H_B - H_A}\right) \left(H_M - \left(\frac{H}{W}\right) W\right)$$

Solving for W:

$$W = \frac{V_{LM} - W_c - \left(\frac{V_{LA} + V_{LB}}{H_A - H_B}\right) H_M}{\frac{V}{W} - \left(\frac{V_{LA} + V_{LB}}{H_A - H_B}\right) \left(\frac{H}{W}\right)} \qquad (20)$$

This is the equation for the mainline limiting live or standing skyline net payload.

The largest errors in rigid link analysis occur when the cables no longer can be idealized as straight line segments. This occurs when the tension in the cable is low and sags appreciably. Looking at a worst case condition to test the mainline limiting payload equation, let the skyline geometry be that depicted in Figure 9. Let the skyline be 1-3/8 inch in diameter and mainline be 7/8 inch in diameter.

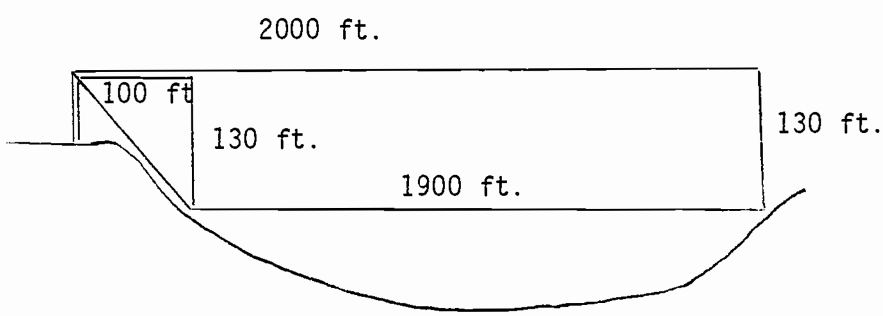


Figure 9. Worst Case Geometry.

The net payload for skyline limiting case is:

$$W = \frac{V_{LA} + 2\ V_{LB} - W_c + (2\ H_B - H_A)\ \frac{h_1}{d_1} - \frac{W_3\ (d_1^{\ 2} + h_1^{\ 2})^{1/2}}{2}}{(\frac{V}{W}) - (\frac{H}{W})\ \frac{h_1}{d_1}} \tag{22}$$

For the minline limiting case,

$$W = \frac{V_{LM} - W_c - (\frac{V_{LA} + 2\ V_{LB}}{H_A - 2\ H_B})\ H_M}{\frac{V}{W} - (\frac{V_{LA} + 2\ V_{LB}}{H_A - 2\ H_B})\ \frac{H}{W}} \tag{23}$$

The worst case in the mainline limiting calculation of running skyline payload results in slightly higher error, compared to the catenary solution. This occurs because there are two skyline (haulback) segments opposing the mainline force applied to the carriage. If the running skyline uses 7/8 inch diameter mainline and haulback, has a 1000 foot span, h_1 = 130 feet, d_1 = 100 feet, and E = 130 feet, the resulting percent error from the catenary solution is 2.5%.

Load Analysis for Live and Standing Skyline Systems Using Clamping Carriages

The program "CLCAR" models the vertical lifting capability of a skyline system using a clamped carriage. As such, it models only the log pick-up phase while the carriage clamp is actuated. Once the carriage begins moving toward the yarder, it must be considered unclamped for analysis. This program analyzes only skyline lifting forces. It assumes the mainline is slack during the log pick-up operation. In the Chain and Board Handbook, Binkley and Sessions

ASSUMPTIONS AND LIMITATIONS OF THE PROGRAMS

1. In the formulation of the vertical and horizontal load forces on the carriage, log diameter was neglected. For logs with long length as compared to diameter, this simplification creates very little error. Peters (1979) developed equations which include the effects of diameter.

2. Cable tensions are analyzed using rigid link formulations. Carson (PNW-205) and Falk (Appendix 2) discuss the error caused.

3. The carriage model analyzed assumes the mainline attaches to the carriage and the mainline balances forces at the carriage. The case of an "active" mainline which passes through the carriage to pull logs to the skyline corridor is not secured to the carriage during inhaul is not analyzed. Three drum (Rowley-Parker) carriage types are also not analyzed.

4. In the running skyline analysis, tension in the slackpulling line is assumed to be zero.

5. Mainline limiting payloads are solved using an approximation formulation. Errors are discussed earlier in this paper.

6. The value of 0.6 is assumed for the coeffficient of friction, the center of gravity is assumed at 0.5 of the log length, and the choker tie point is assumed at 0.9 of the log length from the dragging end of the log. If the user wishes, the values can be changed by accessing the first six program steps in programs "SSL" and "LOAD."

CONCLUSIONS

The programs presented in this paper provide a reasonably complete system for analyzing skyline payloads. These programs can analyze full or partial suspension of logs and uphill or downhill logging situations for live, running, or standing skylines. The programs have been created for use with relatively inexpensive hand-held programmable calculators.

APPENDIX 1

Preface to USER INSTRUCTIONS for Profile Reduction, Load, Standing Skyline, and Clamping Carriage, programs.

In the following set of instructions, commands such as "press USER A" are used several times. This instruction means to press "A" while the calculator is in the "USER" mode. This procedure is accessing local labels within the program.

When using the calculator with a printer, set the printer to the "NORM" mode to get a hard copy of pertinent information.

A final feature to mention is that profile data can be stored on data cards and read from data cards by using "WDTAX" and "RDTAX" commands. (Refer to the H.P. Card Reader Owner's Handbook for details.)

USER INSTRUCTIONS

41-C PR

PROFILE REDUCTION

This program reduces slope distance and percent slope data from a profile survey and stores coordinates for subsequent use with skyline load analysis programs. The program will also accept coordinate input. Data is stored in the form 12345.12345 where the numbers stored left of the decimal point are the "x" coordinate rounded to the nearest 1/10th foot and the numbers right of the decimal are the "y" coordinates. A maximum of 30 profile terrain points can be stored in Registers 01 through 30. Terrain point coordinates can be recalled after data input by recalling the data storage register with the same number as the terrain point. The user must place the decimal point when recalling coordinates.

The calculator must be sized to 33 data storage registers for operation.

STEP	INSTRUCTION	INPUT DATA/UNITS	KEYS	OUTPUT
1	Initialize Storage Registers and Program (Respond to prompts)		XEQ ALPHA PR ALPHA	
2	"DATA TYPE?" displayed a few seconds "COORD=0" displayed a few seconds "%,SL.DIST=1" Enter the number for the type of data entry.			

STEP	INSTRUCTION	INPUT DATA/UNITS	KEYS	OUTPUT
	prompts for the data. If "OK," the program displays "TP 2" and prompts for the next terrain point data.			
3	<u>If entry is for slope distance and percent slope</u>: Enter starting station and elevation after appropriate prompts. "LEG 1" is displayed for a few seconds Then the prompts "SLOPE DIST?" appears			
	Enter slope distance;	Dist. (ft)	R/S	
	"% SLOPE?" appears			
	Enter slope (for example, -30% entered as -30).	SLOPE (%)	R/S	
4	The program redisplays your entries, and asks if your numbers are properly entered "OK? Y=1 N=0"	0	R/S	

5. The choker tie point on the log is assumed to be 90% of the log length from the dragging end (step 07).
6. The yarder is always assumed at the left side of the profile. (Profile terrain points numbered from left to right.)
7. An unclamped carriage is assumed.
8. Rigid link formulations are used in calculating line tensions.

STEP	INSTRUCTION	INPUT DATA/UNITS	KEYS	OUTPUT
1	Access Program		XEQ ALPHA	
	(Respond to prompts)		LOAD ALPHA	
2	"LIVE=1, RUN=0" Enter the type of system to be analyzed	0 -or- 1	R/S	
3	"HS HT" Enter height of yarder	(ft.)	R/S	
4	"TS HT" Enter height of tailspar used	(ft.)	R/S	
5	"CAR WT" Enter carriage weight	(lb.)	R/S	
6	"CHOK LNG" Enter choker length	(ft.)	R/S	
7	"LOG LNG" Enter log length	(ft.)	R/S	
8	"W SL" Enter weight per foot of the skyline	(lb./ft.)	R/S	

STEP	INSTRUCTION	INPUT DATA/UNITS	KEYS	OUTPUT
9	"SWL SL" Enter safe working load of the skyline (if analyzing a running skyline, enter the lesser of yarder interlock tension or skyline safe working load)	(lb.)	R/S	
10	"W ML" Enter the weight per foot of the main-line. If analyzing for running skyline, enter the weight per foot of the mainline + the slackpulling line	(lb./ft.)	R/S	
11	"SWL ML" Enter the safe working load of the mainline If analyzing a live skyline, the calculator will also prompt for haulback specifications:	(lb.)	R/S	
11(LIVE)	"W HB" Enter the weight per foot of the haulback line	(lb./ft.)	R/S	

STEP	INSTRUCTION	INPUT DATA/UNITS	KEYS	OUTPUT
15	"FULL SUSP=0" displayed for a few seconds	0	R/S	
	"PART SUSP=1"	-or-		
	Select type of analysis desired	1		
	OUTPUTS:			
	If the system is skyline limiting and requires a mainline,			
	"T ML" = Mainline tension displayed for a few seconds			T ML (lb.)
	"W =" Payload Displayed			Netload (lb.)
	If the system is mainline limited,			
	"ML LIM" is displayed for a few seconds			
	"W =" Payload based on mainline SWL displayed			Netload (lb.)
	If the system is skyline limited, but needs a haulback to maintain loaded equilibrium,			
	"HB REQ" displayed for a few seconds			

USER INSTRUCTIONS

41 C SSL
STANDING SKYLINE PAYLOAD ANALYSIS

This program analyzes standing skyline payloads for unclamped carriages with full or partial log suspension. The profile should be entered into calculator memory using program "PR" before running this program. This program analyzes both uphill and downhill load paths. Mainline limiting and haulback limiting payloads are also checked.

This program requires the equivalent of 4 memory modules for operation.

The calculator must be sized to 73 data storage registers for operation.

Assumptions in the Program

1. Rigid link formulations are used in calculating line tensions.
2. An unclamped carriage is assumed.
3. The yarder is always assumed at the left side of the profile. (Profile terrain points numbered from left to right.)
4. Minimum carriage clearance on fully suspended loads is based on choker length, log length, and tie point ratio.
5. Carriage clearance is determined based on an assumed elliptical load path.
6. The coefficient of friction for partially suspended loads is assumed as 0.6 (step 07 of program "SSL" contains this number).

STEP	INSTRUCTION	INPUT DATA/UNITS	KEYS	OUTPUT
10	"SWL ML" Enter the safe working load for the mainline	(lb.)	R/S	
11	"W HB" Enter the weight per foot for the haulback	(lb./ft.)	R/S	
12	"SWL HB" Enter the safe working load for the haulback	(lb.)	R/S	
(NOTE:	Steps 2-12 can be re-accessed by pressing USER A)			
13	"HEADSPAR TP" Enter the terrain point number where the yarder is to be placed (must be an integer)	T.P. No.	R/S	
14	"TAILSPAR TP" Enter the number of the terrain point where tail tree is to be located (must be an integer)	T.P. No.	R/S	
15	"IN YD LIM" Enter the number of the terrain point which is the inner yarding limit (generally= headspar TP)	T.P. No.	R/S	

STEP	INSTRUCTION	INPUT DATA/UNITS	KEYS	OUTPUT
	headspar and tailspar			
	and can't be a fraction)			
	OUTPUTS:			
	If the system is skyline			
	limiting and requires a			
	mainline for equilibrium,			
	"T ML = " Mainline tension			
	displayed a few seconds			T ML (lb.)
	"W = " payload displayed.			Net Load (lb.)
	If the user doesn't catch			
	the mainline tension,			
	PRESS X≷Y to return it			
	to the display			
	If the system is mainline			
	limited,			
	"ML LIM" displayed a few			
	seconds			
	"W = " payload based on			Net Load (lb.)
	mainline SWT displayed			
	If the system is skyline			
	limited, but requires a			
	haulback to maintain			
	loaded equilibrium			
	"HB REQ" displayed a few			
	seconds			

USER INSTRUCTIONS

41 C CL CAR

CLAMPED CARRIAGE PAYLOAD ANALYSIS

This program analyzes vertical lifting capability for skylines using a clamped carriage. The profile should be entered into calculator memory using program "PR" before running this program. This program analyzes both uphill and downhill load paths.

This program requires one memory module for operation.

The calculator must be sized to 52 data storage registers for operation.

Assumptions in the Program

1. Rigid link formulations are used in calculating line tensions.
2. A clamping carriage is assumed.
3. The mainline or haulback is assumed to be slack during the log pick up phase. This program calculates tensions only during log pick up - once the carriage is unclamped, analyze with LOAD or SSL.
4. The yarder is assumed at the left side of the profile. (Profile terrain points numbered from left to right.)

NOTE: The user supplies the loaded carriage clearance during the payload analysis for each point. If it is desired to analyze a standing skyline with a clamped carriage, use a program "SSL" to analyze each terrain point of interest and

STEP	INSTRUCTION	INPUT DATA/UNITS	KEYS	OUTPUT
9	"LOAD TP" Enter the terrain point number for payload analysis (must be between headspar and tailspar)	T.P. No.	R/S	
10	"MIN CAR CLR" Enter the loaded carriage clearance	(ft.)	R/S	
	OUTPUT: The program calculates the maximum net lift for the system			
	"W = "			Net Lift (lb.)
11	To continue to the next load point for analysis, press R/S after the payload has been displayed. (To go to step 9 at any time during analysis, press USER C.)			

Data Storage Register No.	"PR"	"LOAD"	"SSL"	"CLCAR"
57		H/W	H/W	
58		V/W	V/W	
59		T_{LA}	T_{LA}	
60		V_{LA}	V_{LA}	
61		V_{LB}	V_{LB}	
62		H_B	H_B	
63		H_A	H_A	
64		W	W	
65			In Yd. Limit	
66			Out. Yd. "	
67			Yarder coord.	
68			Tail coord.	
69			(transient)	
70			(transient)	
71			(transient)	
72			Min. SL length	

The data type is % slope and slope distance, so respond to the prompt with:

1 R/S

Next, respond to the prompt for the initial station,

0 R/S

Respond to the prompt for initial elevation,

4950 R/S

For leg 1, the slope distance is 108 feet,

108 R/S

The % slope is -40%,

-40 R/S

The calculator displays "DIST=108," "SLOPE =-40" which is correct, so respond to "OK? Y=1 N=0" prompt with

1 R/S

The calculator now prompts for the next leg of the profile.

Continue entering data until the whole profile is entered. Remember to respond to the "OK? Y=1 N=0" prompt for the last data point.

EXAMPLE OF LIVE SKYLINE ANALYSIS

Use program "LOAD" for live skyline payload analysis (be sure to size calculator to 65 data storage registers).

XEQ ALPHA LOAD ALPHA

The following data is to be used for analysis:

Tower height = 50 ft. Skyline weight = 1.85 lb./ft.

Tail tree height = 20 ft. Skyline safe working load = 34,500 lb.

Carriage weight = 500 lb. Mainline weight = 1.42 lb./ft.

"T ML = 12,542.192"

"W = 19,989.622"

The mainline tension is displayed briefly before the weight is displayed. To recall the mainline tension after the weight is displayed, press X≷Y.

To continue to analyze the next terrain point, press R/S. Pressing USER C will also return to the "LOAD TP" prompt at any time during analysis.

If the user wishes to change yarder specifications at any point during analysis, pressing USER A will return the program to the prompts for yarder specifications. If the user wishes to change head and/or tailspar location at any time during analysis, press USER B.

The following tables show the rounded results for full suspension analysis and partial suspension analysis.

PARTIAL SUSPENSION

Terrain Point	Net Payload (lb.)	Mainline Tension (lb.)
2	19,900	12,452
3	21,858	11,864
4	13,487	7,561
5	27,543	13,110
6	50,889	2,784

(or, if already within the LOAD program, the user may return to the beginning by pressing USER A.)

Respond to prompts for skyline type, yarder and line specifications given above. Remember to enter the lesser of skyline safe working load or interlock tension when responding to the "SWL SL" prompt.

When responding to the prompt for mainline weight, remember to enter the combined weight of the mainline and slackpulling line.

PROMPT	RESPONSE KEYSTROKES	
"LIVE=1, RUN=0"	0	R/S
"HS HT"	50	R/S
"TS HT"	20	R/S
"CAR WT"	500	R/S
"CHOK LNG"	16	R/S
"LOG LNG"	40	R/S
"W SL"	1.04	R/S
"SWL SL"	19,600	R/S
"W ML"	2.08	R/S
"SWL ML"	19,600	R/S
"HEADSPAR TP"	1	R/S
"TAILSPAR TP"	7	R/S
"LOAD TP"	2	R/S
"FULL SUSP=0" "PART SUSP=1"	1	R/S

At this point the program calculates the net partial suspension payload for TP 2. It returns,

EXAMPLE OF STANDING SKYLINE ANALYSIS - PRGM "SSL"

The following yarder and line specifications will be used to analyze the example profile for a standing skyline configuration.

Tower height = 50 ft.	Skyline weight = 1.85 lb./ft.
Tail tree height = 20 ft.	Skyline safe working load = 34,500 lb.
Carriage weight = 500 lb.	Mainline weight = 1.42 lb./ft.
Choker length = 16 ft.	Mainline safe working load = 26,500 lb.
Log length = 40 ft.	Haulback weight = 0.72 lb./ft.
	Haulback safe working load = 13,700 lb.

Analyze for the yarder at TP 1 and the tailtree at TP 7. Partial suspension is acceptable over the profile.

Yarding limits are from TP 1 to TP 7 and the minimum carriage clearance is 25 feet.

Access beginning of program by pressing:

XEQ ALPHA SSL ALPHA

PROMPT	RESPONSE	KEYSTROKES
"HS HT"	50	R/S
"TS HT"	20	R/S
"CAR WT"	500	R/S
"CHOK LNG"	16	R/S
"LOG LNG"	40	R/S
"W SL"	1.85	R/S
"SWL SL"	34,500	R/S
"W ML"	1.42	R/S
"SWL ML"	26,500	R/S
"W HB"	.72	R/S

RESULTS OF STANDING SKYLINE ANALYSIS

PARTIAL SUSPENSION PERMISSIBLE

Terrain	Net Payload (lb.)	Mainline Tension (lb.)	Carriage Clearance
2	17,629	10,827	25.0
3	13,121	6,631	34.2
4	11,630	6,350	26.1
5	9,928	3,438	48.7
6	11,737*	2,656	61.9

* If full suspension is desired over TP 6 and partial suspension desired over the rest of the profile, the user can check the carriage clearance after evaluating the load at TP 6. In this case the carriage is 61.9 feet above the profile and flying the logs. If the load had been dragging, the user can raise the minimum carriage clearance until logs are flying.

EXAMPLE OF PAYLOAD ANALYSIS FOR A CLAMPING CARRIAGE - PRGM. "CLCAR"

The following yarder and line specifications will be used to analyze the example profile.

Tower height = 50 ft. Skyline weight = 1.85 lb./ft.

Tail tree height = 20 ft. Skyline safe working load = 34,500 lb.

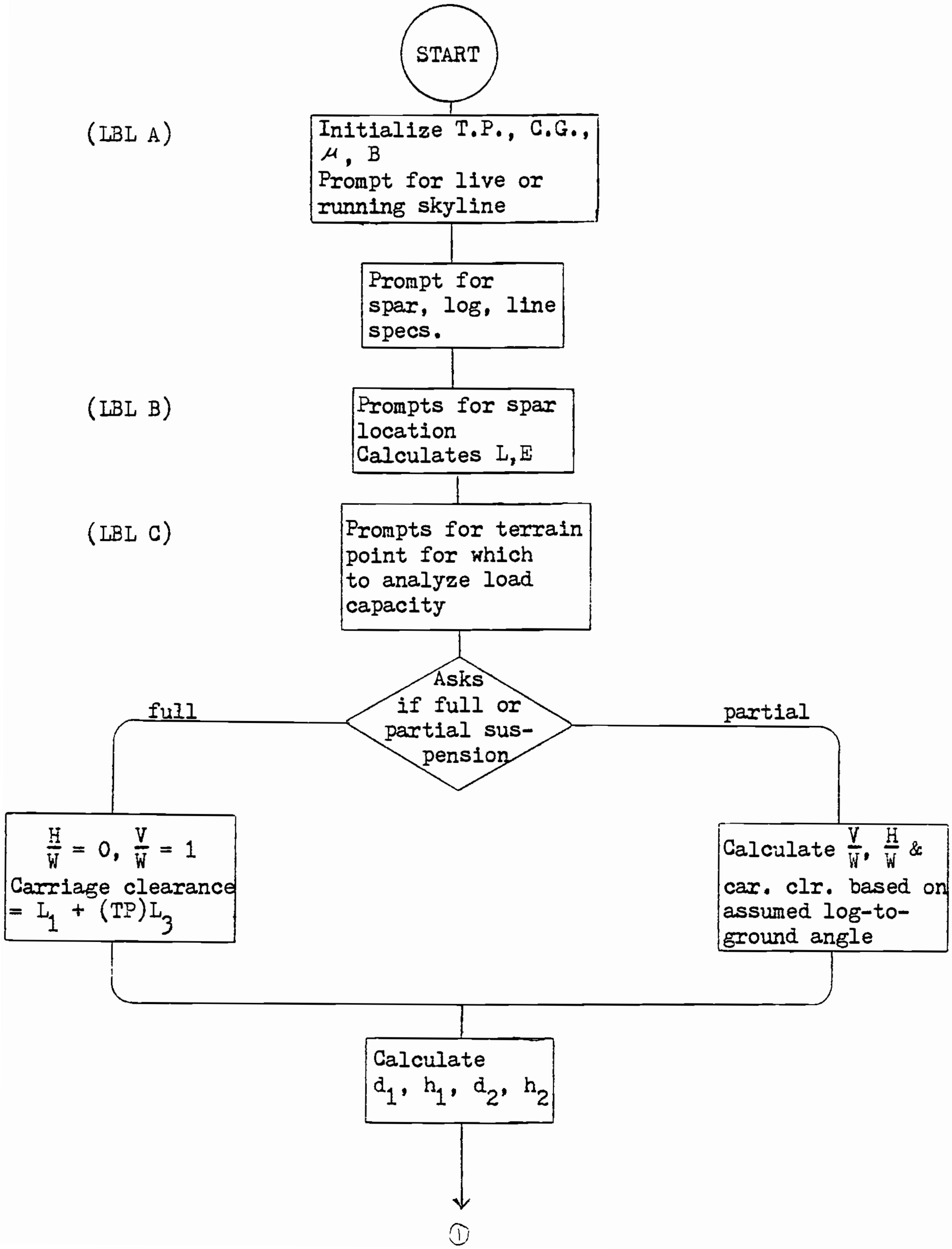
Carriage weight = 500 lb. Live skyline system =

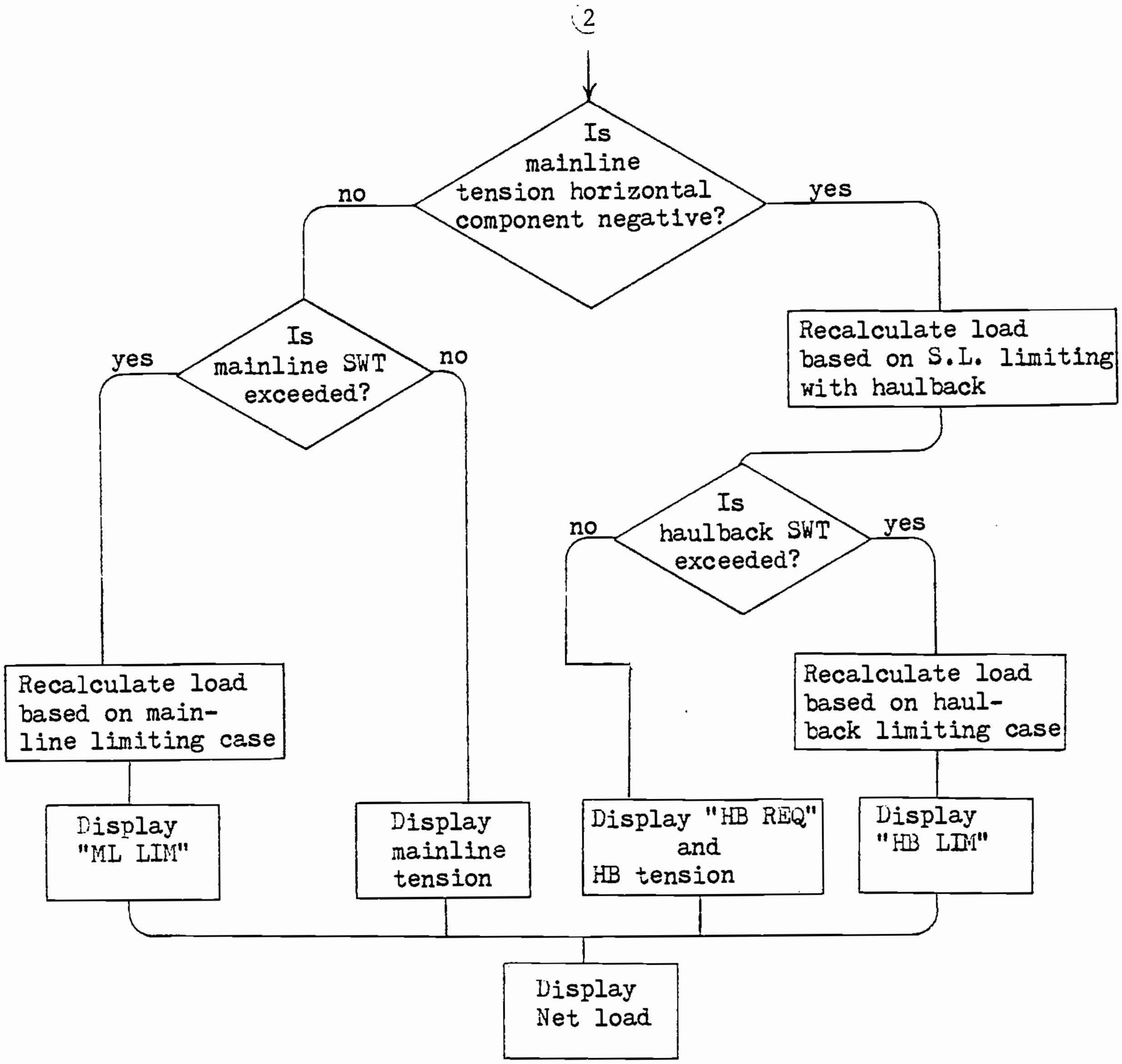
The headspar is to be at TP 1, the tailspar at TP 8. Minimum desired carriage clearance is 52 feet.

Access program with:

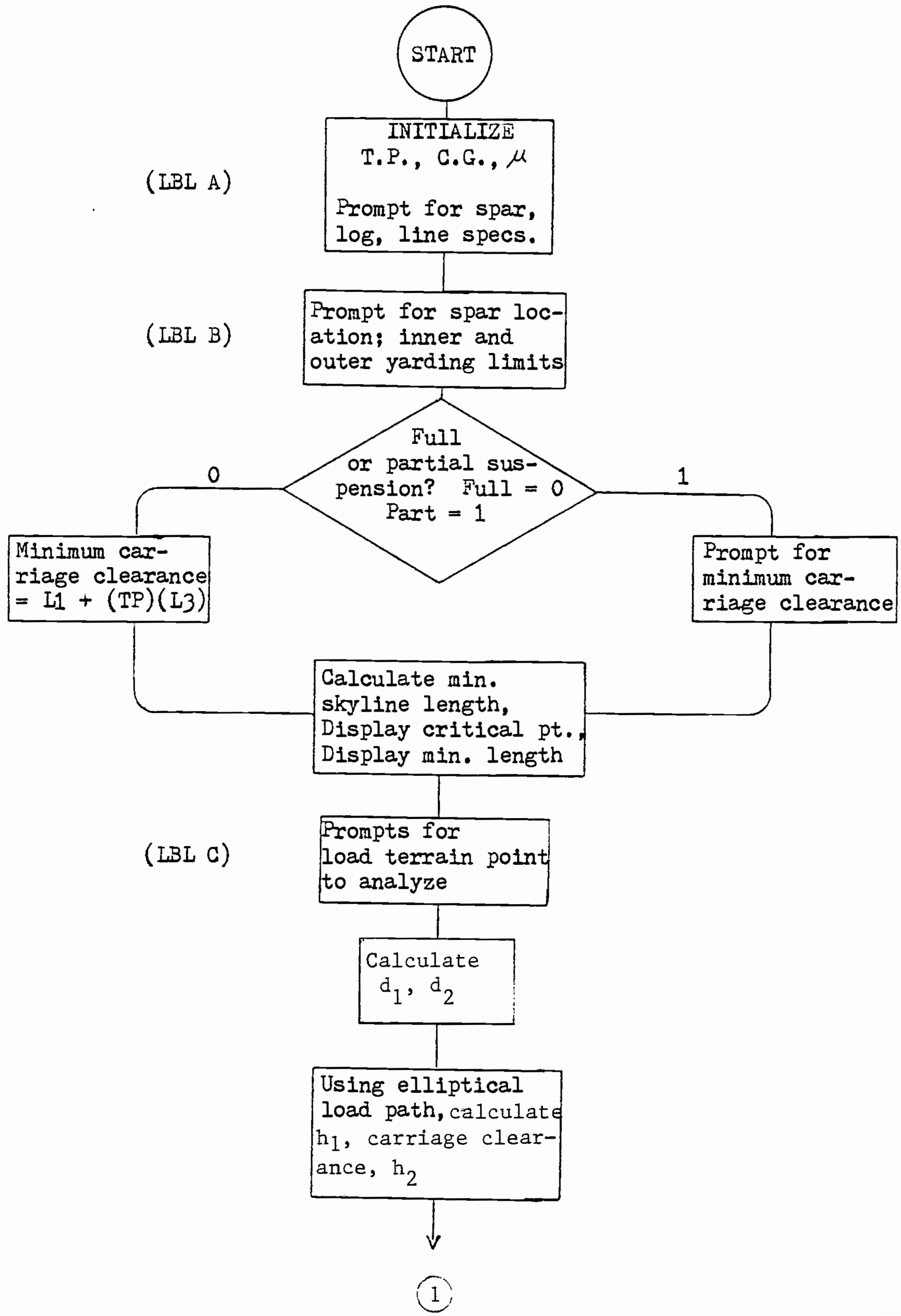
XEQ ALPHA CLCAR ALPHA

FLOW CHART FOR PROGRAM "LOAD"




2
Is mainline tension horizontal component negative?
no
yes
Is mainline SWT exceeded?
yes
no
Recalculate load based on S.L. limiting with haulback
Is haulback SWT exceeded?
no
yes
Recalculate load based on main-line limiting case
Recalculate load based on haul-back limiting case
Display "ML LIM"
Display mainline tension
Display "HB REQ" and HB tension
Display "HB LIM"
Display Net load

FLOW CHART FOR PROGRAM "SSL"



APPENDIX 2

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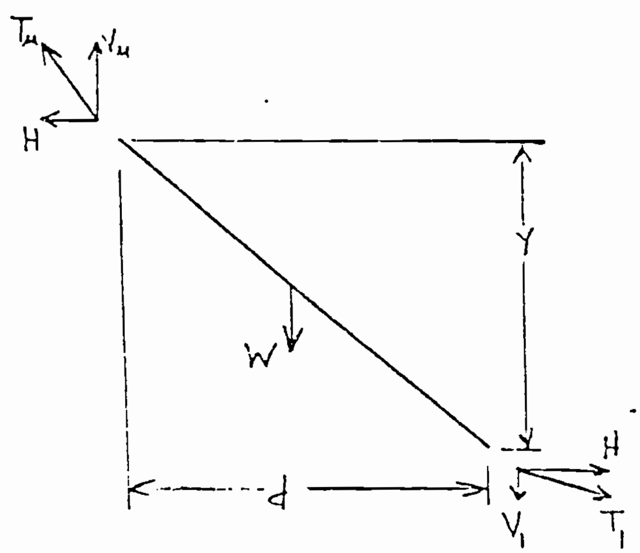
The Improved Rigid Link Formulation

One of the basic problems in skyline analyses is determining the relationship between the tension in a cable segment and the associated horizontal and vertical force components. The exact relationship involves the catenary curve for which there is usually no direct solution using the parameters that are known in the most common skyline mechanics applications. The rigid link formulated by Carson satisfactorily approximates this relationship for skyline applications. However, in developing improved algorithms and techniques for predicting payload capability by accounting for the effects of partial suspension, an improved rigid link equation was formulated. As it turns out, this formulation is not only much simpler, it also approximates the catenary solution more closely than what has been traditionally used. Given the allowable tension in a cable segment, the geometry, and the cable weight per unit length, the derivation of this relationship is as follows.

Figure 1 shows the geometry and the tensions at the upper and lower end of the cable segment. Since there are no external horizontal forces on the system these tensions can be resolved into horizontal and vertical components as shown



T_u = Tension at upper end of cable segment
T_l = Tension at lower end of cable segment
H = Horizontal component of cable tension
V_u = Vertical component at upper end
V_l = Vertical component at lower end
d = horizontal distance
y = elevation difference
W = Cable segment weight
ω = Cable weight per unit length

Figure 1 - Force components and known parameters