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The Weak Link HP-41C Hand-held Calculator Program

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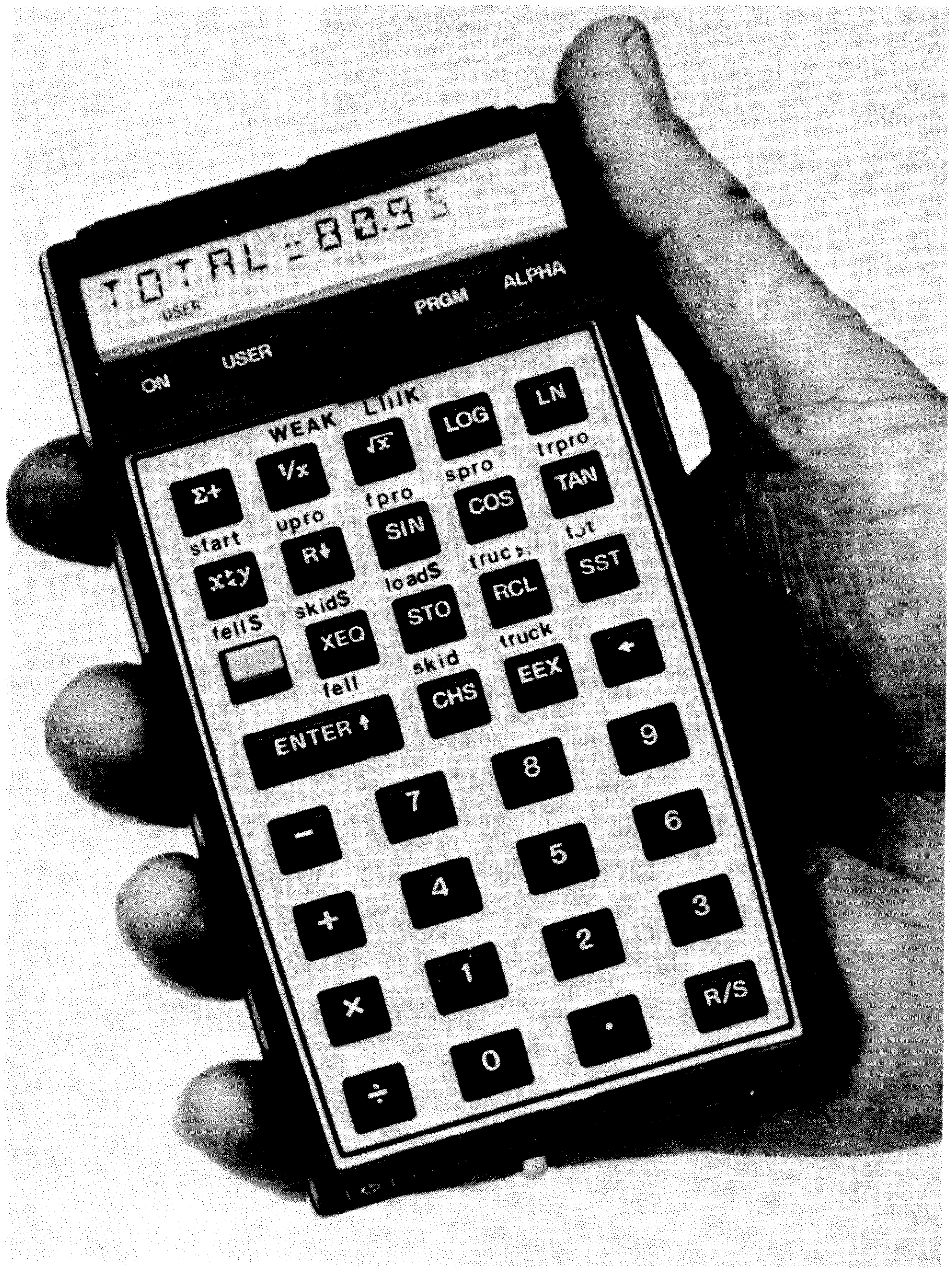

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Abstract

The Weak Link hand-held calculator program (HP-41C) quickly analyzes a system for logging production and costs. The production equations model conventional chain saw, skidder, loader, and tandem-axle truck operations in eastern mountain areas. Production of each function of the logging system may be determined so that the system may be balanced for minimum cost. The user supplies input data, and the program calculates cost rates for the various functions of logging. The final output is logging costs in dollars per M bf (thousand board feet).

Introduction

The Weak Link Logging Systems Analyzer (Baumgras and Martin 1978) was accepted by users, probably because of the relative ease of making calculations for cost analysis of logging operations by the use of nomograms. Ease of use has been furthered by programming the formulas used in generating the Analyzer for solution by a programmable hand-held calculator, the Hewlett-Packard 41C.[1]

The program described here solves the same problems as the Analyzer, but with greater speed. Consider the program a supplement to the Analyzer. The program requests input for which the Analyzer lists recommended values. If you do not have a copy, you may request *The Weak Link Logging System Analyzer* (GTR-NE-40) from National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22151, Accession Number PB 80 218241, February 1982 cost: $9.00.

Production equations used in the program are identical to those used in the Analyzer. They model conventional chain saw, skidder, loader, and tandem-axle truck operations in eastern mountain areas. Cost calculations in the program are different from those used in the Analyzer. Overhead in the Analyzer starts with the annual overhead which is reduced to overhead per shift. Overhead in the program must be input as a percentage of wages, percentage of average investment, or a percentage of depreciation. The latter inputs can be used to compare individual machines or to get a more accurate comparison of labor costs and machine costs.

[1] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

The principal problems addressed by the Weak Link are manual felling, rubber-tired and crawler skidding operations, and trucking. Calculators give answers fast, so rapid estimates for logging costs can be obtained in the field. This program was written for the Hewlett-Packard 41C calculator and requires three extra memory modules or a quadmodule to hold the program (some 1700 bytes). The only other item needed for use is a knowledge of the units used in the program. The calculator prompts the operator for the needed data and then gives the answers on demand.

This program is on magnetic cards. The card reader for the HP-41C calculator will load the program in less than a minute. The computer program described in this publication is available on request with the understanding that the U.S. Department of Agriculture cannot assure its accuracy, completeness, reliability, or suitability for any other purpose than that reported. The recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a Government-produced computer program. For information, please write: Engineering Research, Northeastern Forest Experiment Station, 180 Canfield Street, Morgantown, WV 26505. If you want to obtain the program, send seven blank Hewlett-Packard magnetic cards. Features of the HP-41C are presented in Appendix A. A program list is provided in Appendix B. Nomenclature for keys and displays is given in Appendix C.

First-Time User Instructions

Depress the switch marked USER and then enter the program. USER appears on the view screen; neither PRGM nor ALPHA should appear. The alphabet is printed on the keys of the calculator along with symbols and numerals. The USER key activates the reassigned keys. The alphabet designates the keys to be used for this program when instructions call for pressing a key designated by a letter.

Press A to start the program. An execution annunciator appears that somewhat resembles a bird flying across the screen, and PRGM appears while the program is running. The program prompts for various inputs. Three example problems are presented in this paper; problem 1 will be worked in detail to illustrate the use of the program (Table 1). Prompting notations can be changed to please the operator, so long as the total number of characters including blanks does not exceed 12. The program contains three input sections: felling, skidding, and trucking data. The calculator signals the end of each section.

Felling Data

The first prompt, DBH H, asks for two inputs. The first is diameter at breast height in inches, and the second is the height of the tree in logs (16-foot length). Use average values for the tract of timber being analyzed. Decimals of the input units may be used. The example uses 18 inches for the diameter and 2 logs for the height. Key 18 into the calculator, then ENTER↑, then 2, and then R/S.

When more than two entries exist, press the R/S key after the last input; press the ENTER↑ key after each item in a series of entries except the last one. If only one item exists in the prompt, press only the R/S key. The letters R/S stand for run and stop. If the program is running, this key stops it. If the program is not running, the run command starts it again. The program has stops at appropriate places, but run must be manually executed.

Table 1.—Fell, skid, and truck input data for Problems 1, 2, 3

Input data	Problem 1	Problem 2	Problem 3
DBH (inches)	18	24	16
H (16-foot logs)	2	2	1.5
V1 (M bf)	0.2	0.3	0.17
V2 (M bf)	0.07	0.14	0.07
WT (minutes)	0.6	0.7	0.6
$ PER HR?	1	∅	1
D (feet)	2,000	1,500	1,000
S/S	2	2	3
S/T	2	2	3
LEVEL?	∅	∅	1
UPHILL?	∅	1	NA
BUNCH?	∅	1	∅
DT (minutes)	3.7	2.9	3.2
SA	0.85	0.88	0.82
CAP (M bf)	2.5	3.00	2.3
D1 (miles)	20	15	10
D2 (miles)	10	3	6
D3 (miles)	2	2	3
D4 (miles)	2	1	2
TU (minutes)	7	6	9
TD (minutes)	24	8	20
TA	0.90	0.92	0.88

The next prompt, V1 V2, asks for the volume of the tree and the volume per log. Use average values for the entire tract. The volume per log is the average volume per log loaded on the truck and is not necessarily the volume of the average 16-foot log. The example gives an average value of 0.2 M bf (thousand board feet) per tree and an average value of 0.07 M bf per log.

The next prompt, WT, asks for the average walking time, in minutes, from the tree just felled to the next tree. Slope influences walking time, which generally ranges from 0.6 minutes to 1.4 minutes per tree. Use observed times on a similar logging job if possible. The example uses an average of 0.6 minutes to get to the next tree.

The next prompt, $ PER HR?, asks if the feller gets paid by the hour. The alternative would be production pay or so much per M bf. A "yes" or "no" answers this prompt. Throughout the program use 1 for "yes" and Ø for "no". The example uses an hourly wage, thus enter 1. END FELL appears followed by D S/S S/T.

Assignment of user keys permits entering the program at various locations. After pressing a user key other than A, the program will not proceed from one section to the next without pressing the proper user key. Limitations of reentering data are described later.

Skidding Data

The prompt D S/S S/T introduces skidding. D asks for the average skidding distance in feet; S/S, the average number of trees pulled by the rubber-tired skidder; and S/T, the average number of trees pulled by the crawler tractor. Example values are 2,000, 2, and 2. Information that does not apply to the desired answer will not affect the answer. Thus, if only rubber-tired skidders are used, the number of stems pulled by crawler tractors will have no effect on rubber-tired skidder production.

After these entries, the prompt LEVEL? asks if the skidding will be along level terrain. It requires a "yes" or "no" answer. If "no" is given, the prompt UPHILL? asks if the skidding will be uphill. If "no" for uphill, then downhill is left, however, if the operator replies "yes" to level, then the next prompt shows "BUNCH?". Again, use "yes" or "no". Bunching increases the skidder production. However, the program does not provide for the cost of the bunching machine as such, but a bunching tractor can be included with the skidders. This is explained later. In the example, downhill skidding with no bunching is specified. Therefore, enter LEVEL? = Ø, UPHILL? = Ø, and BUNCH? = Ø.

The next prompt, DT, requires a numerical value for skidding delay time in minutes per turn. The example uses 3.7 minutes delay time per turn. Average self-caused delay time generally ranges from slightly over 1 minute to less than 4 minutes, depending on the aggressiveness of the operator. Observation of the available operator will give the best input value.

The next prompt, SA, asks for machine availability which represents the percentage of scheduled machine time that the machine is mechanically fit to do productive work. The example uses 0.85 for SA for skidding equipment. END SKID signals the end of skidding input.

Trucking Data

The first trucking data prompt, CAP, asks for the average truck capacity in M bf. The example uses 2.5 M bf. The next prompt, D1 D2, asks for two distances in miles. D1 asks for the hauling distance on a two-lane paved road; the example uses 20 miles. D2 asks for one-lane paved road distance; the example uses 10 miles. The next prompt, D3 D4, also asks for distance in miles. D3 asks for distance on a one-lane gravel road and D4 asks for distance on a woods road. The example uses 2 miles for each of these. The next prompt, TU TD, asks for truck unloading time in minutes and truck delay time in minutes. Delay time refers to delays caused by the driver. It does not refer to time spent waiting for some other piece of equipment or logs. The example uses 7 minutes unloading time and 24 minutes delay time. Both times are averages from time studies. Of course, observed times of the concerned workers should be used. The last prompt, TA, asks for truck availability. The example uses 0.90. END TRUCK appears on the screen, and the next step is to get some answers.

Production Output

The first answer is UFPRO (unit felling production) = 1.43. This may be obtained by pressing B or R/S. The value 1.43 is the number of M bf that one feller can cut in 1 hour. All production outputs are given in M bf per hour. Next, push R/S and USPRO (unit skidding production) = 1.25 appears.

Pressing R/S again will display UTPRO = 1.05. This shows skidding production for crawler tractors. Either rubber-tired skidders or crawler tractors may be used in this program, or the combination may be used. After pressing R/S again, ULPRO = 3.62 appears. This indicates that the loader can load 3.62 M bf of logs per hour. This program assumes that the loader does not limit system production. After activating R/S again, UTRPRO = 0.50 appears. This readout concludes the series, and unit truck production equals 0.50 M bf per hour.

The program can be reentered at various places. Press B and the first of the unit production series appears. By using R/S, the entire series may be viewed. The user may write the answers for an overall view rather than use the calculator to view the answers one at a time. If written, we suggest a tabular form with three columns added to facilitate the next step of balancing the production for the operation. The suggested format is shown in Table 2; the production numbers for problem 1 correspond to the example.

The next procedure may be obtained by pressing C. The prompt shows NF H/D, which asks for the number of fellers and the hours per day that they work. The entry of 2 fellers and 8 hours per day shows FPRO = 22.89, which indicates the felling production of 22.89 M bf per day with 2 workers. Hours per day may be changed for different production. These data are also recorded in Table 2.

By pressing R/S, 22.89 appears and the number may be used with any arithmetical procedure such as division, addition, subtraction, and multiplication. The next press of R/S displays the prompt NS H/D, or this prompt may be obtained by pressing D. The prompt NS H/D asks for the number of rubber-tired skidding units and the hours per day that they are used. The entry of 2 units and 8 hours per day shows SPRO = 20.03, which indicates the skidding production of 20.03 M bf per 8 hour day with 2 rubber-tired skidders. Changing hours per day readily changes production, and the number of skidders also changes production. When the number of skidders change, remember to change the number of skidders in the cost section.

By pressing R/S, the prompt NT H/D asks for the number of units of skidding tractors and the hours per day that they work. Assume that only rubber-tired skidders are used and enter ∅ units and ∅ hours. In the event that only crawler tractors did the skidding, zero entries would be made for the rubber-tired skidders.

Table 2.—Production by logging system functions

Function	M bf unit	Number of units	Hours/day	M bf/day
		PROBLEM 1		
Felling	1.43	2	8	22.89
Rubber-tired skidding	1.25	2	8	20.03
Tractor skidding	1.05	∅	∅	∅
Total skidding	NA	NA	NA	20.03
Loading	3.62	NA	NA	NA
Trucking	0.50	4	10	20.00
		PROBLEM 2		
Felling	2.06	2	8	32.91
Rubber-tired skidding	2.39	∅	∅	∅
Tractor skidding	1.93	2	8	30.90
Total skidding	NA	NA	NA	30.90
Loading	6.75	NA	NA	NA
Trucking	1.00	4	9.1	36.00
		PROBLEM 3		
Felling	1.38	2	7	19.33
Rubber-tired skidding	1.58	1	7	11.07
Tractor skidding	1.32	1	5	6.60
Total skidding	NA	NA	NA	17.67
Loading	3.59	NA	NA	NA
Trucking	0.55	4	8.5	18.40

After inputting zeros and pressing R/S, the screen shows TPRO = ∅.∅∅. Press R/S again, and S + TPRO = 20.03 shows on the screen. S + TPRO indicates the total daily skidding production. The next use of R/S shows 20.03. This number may be used as desired with the various arithmetical functions of the calculator. Previous numbers on the screen could not be acted upon directly.

Continue with either R/S or E, and NTR H/D asks for the number of trucks and the hours per day that they operate. The entry of 4 trucks at 10 hours per day shows TRPRO = 20.00 or 20 M bf per day for trucking production. Pressing R/S shows 20.00 on the screen.

If the daily production of either felling, skidding, or trucking is substantially different from the others, this item may be recalculated for a different number of units or hours per day or both. Press C to reenter the program for felling production, D for skidding production, and E for trucking production. These three keys may be used in any order and as frequently as desired. Felling and skidding calculations give continuous answers. The truck calculations give incremental answers. Approximately 5 hours are required to make a trip with the sample input. Thus, both 6 and 9 hours give the same production for trucking with this example. Increased production shows at 10 hours, and the next increase will show at about 15 hours. Different trip conditions will change this incremental time.

Our sample problem uses 2 fellers for 8 hours and 2 skidders for 8 hours. Note that by using 2 fellers for 7 hours the total production would be nearer even. Other factors may outweigh the precise balancing of total production. Working shorter hours may cause dissension among the workers, and a feller may be the owner's son-in-law.

Cost Input

After production factors are closely balanced, start costing procedures to obtain the ultimate answer in dollars per M bf. Press F and FELL COSTS appears, followed by the prompt VC VS. This prompt asks for the initial cost and the salvage value of the equipment. Costs are usually known; salvage values must be estimated. The example uses an initial cost of $450 for saws and a salvage value of zero (Table 3).

Table 3.—Cost input data for Problem 1

Input data	Fell	Skid	Load	Truck	
VC ($)	450	50,000	20,000	18,000	17,500
VS ($)	Ø	5,000	4,000	2,000	1,000
RI	0.10	0.10	0.10	0.10	0.10
RM	0.15	0.15	0.15	0.15	0.15
N (years)	1	5	10	4	4
RR	0.80	0.40	0.30	0.35	0.35
HRS PER YR	1800	1500	1200	1700	1700
NO OF PCS	2	2	1	2	2
NO	2	2	1	4	
RATE ($/hour)	5.75	6.00	5.50	5.50	
NO		1			
RATE ($/Hour)		5.50			
RB	0.30	0.30	0.30	0.30	
RO	0.20	0.20	02.0	0.20	
SAPCOSTS ($/OP.HR)	0.80				
SOPCOSTS ($/OP.HR)		6.00			
TOPCOSTS ($/OP.HR)		Ø			
LOPCOSTS ($/OP.HR)			2.50		
TROPCOSTS ($/OP.HR)				5.00	

The next prompt, RI RM, asks for interest rate and maintenance rate. They are multiplied by average investment to obtain annual interest charges and maintenance costs. Maintenance for saws includes files, spark plugs, and other minor items including other machine overhead. Use the best available value for both of these and enter as a decimal. The example uses 0.10 for interest and 0.15 for maintenance.

The next prompt, N, asks for the number of years of useful life of the machine or depreciation period. The practical range here probably would be 1 to 10 years, and the number of years influences the input for the following prompt, RR, which asks for the repair rate. Enter repair rate as a percentage of yearly depreciation, which could be quite low or could go over 100 percent depending on the equipment and operating conditions. For example, if the original costs is $2,500 with no salvage value, the depreciation period 5 years, and the estimated annual repair costs $200; then the annual depreciation is $500, and repair costs are 40 percent of the annual depreciation. Enter all percentages as decimals. For the example, use 1 year of life and 0.80 for the repair rate for chain saws.

The next prompt, HRS PER YR, asks for the average number of hours of use per year. To estimate, use 40 hours per week for 50 weeks, which is 2,000 hours. Then consider time lost because of repairs and inclement weather. We used 1,800 hours for the example. Of course, more than 2,000 hours could be worked by extending work weeks and the 8-hour day, or by double shift work.

The next prompt, NO OF PCS, asks for the number of saws that fit in the above category; we used 2 for the example. Because many loggers with more than one saw have different models or at least one of the input factors differ from the other saws, the prompt VC VS shows. This starts the felling cost calculation again for other saws.

After entering data for all of the saws, enter Ø for VC and Ø for VS. The prompt NO RATE then asks for the number of fellers and the dollars per hour that they are paid. Because different pay scale rates may be used, this prompt also repeats for as many times as needed. We used two workers at $5.75 per hour for the example. Use the same process to pass this loop as that used to pass the previous loop. After entering 2 and 5.75 enter Ø for the number of workers and Ø for the rate of pay and the prompt RB RO appears. This applies to all personnel and asks for the percentage of wages paid for benefits and the percentage of wages paid for overhead. Benefits include social security, paid vacations, holiday gifts, unemployment compensation, and other expenditures directly related to the individuals' payroll. Overhead includes pay for supervisors, foremen, payroll clerks, secretaries, office rent, and other items necessary to keep the woods crew operating. Show the portion of overhead costs allocated to felling in this entry. Values used for the example are 0.30 for RB and 0.20 for RO.

The next prompt, SAPCOSTS, asks for felling operating costs in dollars per hour for each saw. Operating costs include fuel, lubricants, and any other ongoing expense directly related to the equipment that was not included with maintenance. The example uses 0.80. Pressing R/S again displays the value that was input for felling operating costs. Another press of R/S starts the skidding cost sequence, or press G to get the skidding cost sequence.

SKID COSTS appears on the screen followed by the prompt VC VS, which asks for the cost value and the salvage value of a skidder. These values are $50,000 and $5,000. Continue to make inputs from data given in Table 3. The example contains two skidders with the same values. We used three workers—an operator for each skidder and a chokersetter. Values for the various workers accumulate so that extra costs pertaining to skidding may be entered. After the prompt SOPCOSTS, which asks for the skidder operating costs, has been answered and entered by R/S, TRACTOR COSTS appears on the screen followed by the prompt VC VS. This applies to skidding tractors. If the operation uses no skidding tractors, as in this sample problem, enter zero and zero for the prompts and NO RATE appears, which asks for the number of operators and their hourly rate. Again enter zero and zero and the prompt, RV RO appears.

Because this asks for the percentage of wages for benefits and overhead, and no wages exist, zeros may be entered or any other number will give the same answer. The next prompt, TOPCOSTS, asks for the tractor operating costs, which are zero. When the operation uses a bunching tractor, it may be entered with the skidding tractors. Example number two (Table 4) uses tractors for skidding rather than rubber-tired skidders, so the zero values go in the rubber-tired skidder section. Example number three (Table 5) uses both a rubber-tired skidder and a tractor so enter values in both sections.

Table 4.—Cost input data for Problem 2

Input data	Fell	Skid			Load	Truck
		TR#1	TR#2	Bunch		
VC ($)		58,0000	64,000	40,000	25,000	21,000
VS($)		3,000	5,000	4,000	2,000	6,000
RI		0.12	0.12	0.12	0.12	0.14
RM		0.12	0.14	0.10	0.08	0.15
N (years)		3	4	6	8	5
RR		0.10	0.08	0.15	0.05	0.15
HRS PER YR		1800	1800	1600	1000	2000
NO O PCS		1	1	1	1	4
NO			2		1	2
RATE ($/hour)			6.00		7.50	6.50
NO			2			2
RATE ($/hour)			7.50			7.00
NO			1			
RATE ($/hour)			7.00			
RB			0.28		0.28	0.28
RO			0.10		0.10	0.12
SAPCOSTS ($/OP.hour)						
SOPCOSTS ($/OP.hour)						
TOPCOSTS ($/OP.hour)			6.00			
LOPCOSTS ($/OP.hour)					4.00	
TROPCOSTS ($/OP.hour)						6.00

Table 5.—Cost input data for Problem 3

Input data	Fell	Skid		Load	Truck
		Skidder	Tractor		
VC (4)	450	52,000	58,000	30,000	21,000
VS ($)	∅	5,000	3,000	10,000	6,000
RI	0.14	0.12	0.12	0.14	0.15
RM	0.20	0.15	0.12	0.12	0.15
N (years)	2	5	4	10	5
RR	0.90	0.20	0.15	0.10	0.15
HRS PER YR	2,000	1,800	1,200	1,200	2,000
NO OF PCS	2	1	1	1	4
NO	2	1	1	1	4
RATE ($/hour)	6.50	7.00	7.00	7.00	6.75
NO		1	1		
RATE ($/hour)		6.50	6.50		
RB	0.30	0.30	0.30	0.30	0.30
RO	0.10	0.10	0.10	0.10	0.10
SAPCOSTS ($/Op. hour)	1.00				
SOPCOSTS ($/Op. hour)		6.50			
TOPCOSTS ($/Op. hour)			6.00		
LOPCOSTS ($/Op. hour)				4.50	
TROPCOSTS ($/Op. hour)					7.00

Press H to start the load section and LOAD COSTS shows on the screen. The first prompt, VC VS, asks for cost value and salvage of the loader, and prompts follow the same sequences as that for felling and skidding equipment.

Press I and TRUCK COSTS appears followed by the prompt VC VS. This sequence of prompts is the same as that for felling costs, skidding costs, and loading costs except for the last prompt, TROPCOSTS, which asks for truck operating costs. The four items of felling, skidding, loading, and trucking costs may be entered in any order.

Logging Cost

Start the final sequence of the program by pressing J, and the prompt AC PRO shows, which asks for actual production. Enter the lowest figure obtained from the daily production values for felling, skidding, or trucking. Use the lowest figure because the other functions of harvesting will slow down to meet this low production function—the weak link. Because the trucking production was low with 20 M bf per day, enter 20 for the example. After pressing R/S, FELL = 8.04 appears which is the actual felling costs in dollars per M bf. The assumption is made that reducing the output of the felling operation would not reduce any of the costs. Pressing R/S shows SKID = 25.06, which indicates the skidding costs. The next display LOAD = 5.88 is the loading cost followed by TRUCK = 33.58, the trucking costs. The next step obtained by pressing R/S shows TOTAL = 72.56, which indicates that the total logging cost is $72.56 per M bf (Table 6). The next use of R/S gives 72.56, which may be used for calculations. This step ends the calculations.

Table 6.—Logging cost by function as determined by weak link producton

Function	Problem 1	Problem 2	Problem 3
AC PRO (M bf/day)	20	30.9	17.67
FCOST ($/M bf)		14.0	
FELL ($/M bf)	8.04	14.0	8.02
SKID ($/M bf)	25.06	24.78	29.20
LOAD	5.88	4.88	8.68
TRUCK ($/M bf)	33.58	20.18	33.94
TOTAL ($/M bf)	72.56	63.84	79.84

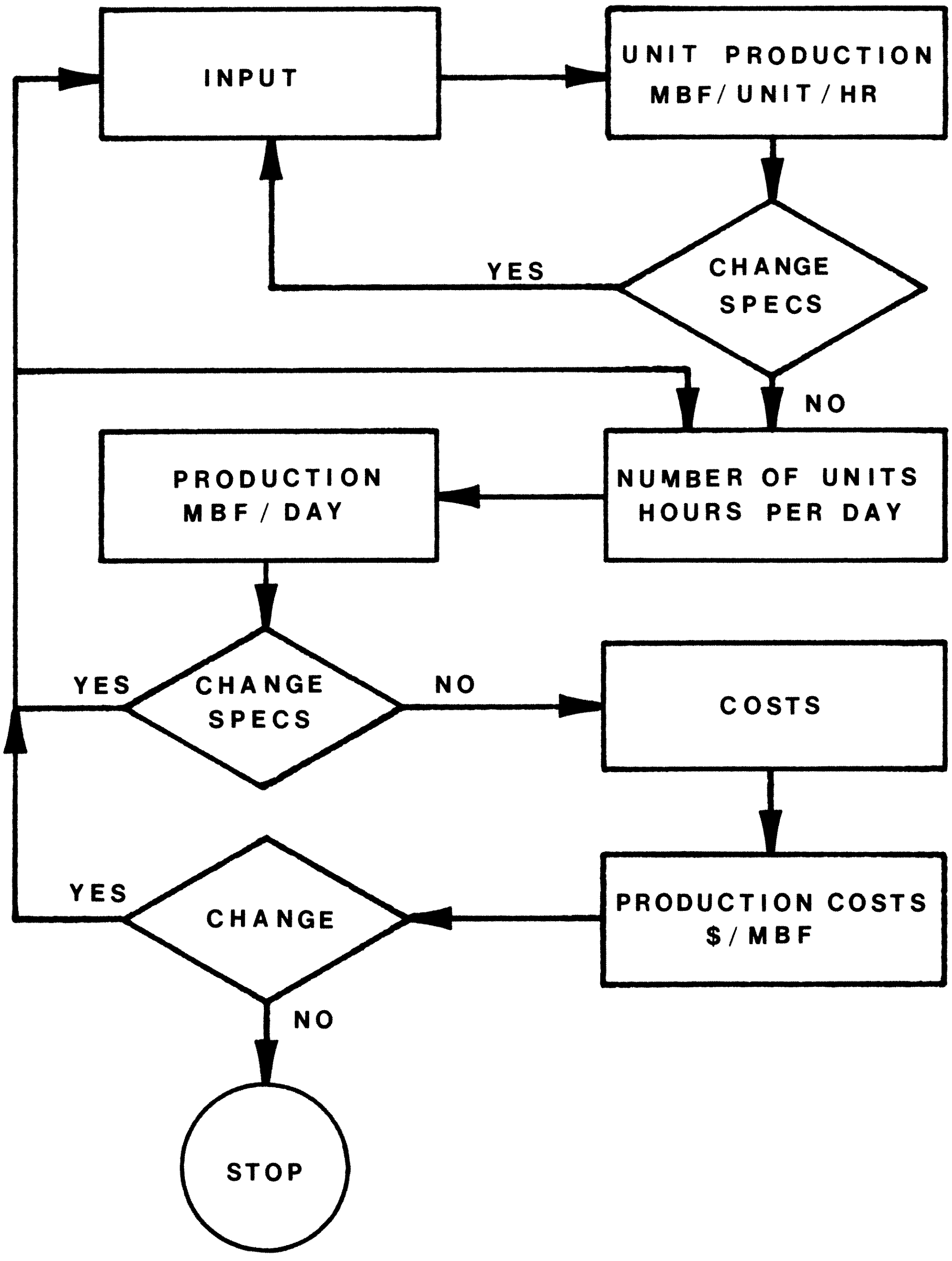

Figure 1.—Flow diagram for weak link hand-held computer program

Reentering Data

The program user may want to change some inputs and calculate the effect on production and cost without reentering data for the whole program. The instructions for reentering data are organized by the following categories: (1) daily production; (2) hours per day; (3) owning, operating, and labor costs; and (4) fell, skid, and truck input data. In addition to the desired change, it may be necessary to reenter some data because of the structures of the program. Specific instructions follow.

Daily Production

The daily production is entered as AC PRO in the calculation of logging system costs (J). In the weak link method of determining costs, AC PRO is the minimum daily production achieved by either felling, skidding, or trucking production. The following example illustrates the reentering of data for AC PRO.

In Problem 1, the minimum daily production of 20 M bf per day resulted in felling costs of $8.04 per M bf. To determine how much additional felling cost we were incurring because production was limited to 20 M bf per day when fellers had the capability of producing 22.89 M bf per day, we pressed J, entered 22.89 for AC PRO to get the optimum felling costs. Felling costs = $7.09 per M bf indicating that if the rest of the system had been capable of producing 22.89 M bf per day, felling costs could be reduced by $0.95 per M bf. Changes to AC PRO (J) can be made without reentering data for other keys.

Hours Per Day

The daily production that can be obtained can be adjusted by changing the working hours per day for felling, skidding, and trucking. Data for hours per day can be reentered by pressing C for felling, D for skidding, or E for trucking. After reentering data, press J and reenter actual production to obtain results. The number of units working could also be changed, but the appropriate cost data should also be reentered to reflect the additional costs associated with additional units. This applies only to item changes such as skidders.

Owning, Operating, and Labor Costs

Data can be reentered for owning, operating, and labor costs by pressing the appropriate key: F for felling costs, G for skidding costs, H for loading costs, or I for trucking costs. Data do not have to be reentered for any other keys. For example, if felling labor rates increased, press F, enter the data required (even enter values that have not changed). When finished, press J and reenter actual production to obtain results.

Fell, Skid, and Truck Input Data

K, L, and M allow you to reenter data that affect the unit felling, skidding, and the trucking production per hour, respectively. The data that can be reentered by pressing K, L, and M are inputs DBH through TA shown in Table 1. Rules for reentering data in K, L, or M:

(1) If variables DBH, H, WT, or $ PER HR? are changed, reenter data in K.

(2) If variables V, D, S/S, S/T, LEVEL?, UPHILL?, BUNCH?, DT, and SA are changed, reenter data in K and L.

(3) If variables V2, CAP, D1, D2, D3, D4, TU, TD, or TA are changed, reenter data in K and M.

When data have been reentered, complete the problem by pressing B, C, D, E, (F, G, H, and I, if required) and J.

Literature Cited

Baumgras, John E.; Martin, A. Jeff. **The weak link logging systems analyzer.** 1978; USDA For. Serv. Gen. Tech. Rep. NE-40. 63 p.

Appendix A

Calculator Description

The hand-held Hewlett-Packard 41C contains programmable capabilities and a reasonably extensive storage. The calculator was designed for easy entrance of program storage. The program may be entered by direct programming, which is relatively simple, or through magnetic cards. Magnetic cards offer quick recovery of the program after some interruption such as using another program. The calculator's continuous memory holds the program as long as the storage space is not used for something else and even when the calculator is turned off. The reader will also transfer a program to magnetic cards.

Visual prompting for data shows on the visual display of the calculator so the program can readily be used at logging sites or any other place where a quick answer would be desirable. The operator needs to remember the abbreviations displayed and the units for the data to be entered.

Reassignment of key functions of the calculator facilitates entering the program at any program location so that input may be changed quickly and the answers may be obtained without going through the whole program.

The calculator signals for low batteries when BAT appears in the lower left side of the viewscreen. This signal indicates the need for a battery change. Old batteries may cause erratic functions of a program, even before the calculator indicates a need for battery change.

Appendix B

Weak Link HP-41C Program List

User Keys:

```
11 "START"
12 "UPRO"
13 "FPRO"
14 "SKPRO"
15 "TRPRO"
21 "FCOSTS"
22 "SCOSTS"
23 "LCOST"
24 "TRCOSTS"
25 "ACOST"
32 "FELL"
33 "SKID"
34 "TRUCK"
```

```
01 LBL "START"
02 XEQ "FELL"
03 XEQ "SKID"
04 XEQ "TRUCK"
05 XEQ "UPRO"
06 LBL "FPRO"
07 "NF H/D"
08 PROMPT
09 STO 17
10 *
11 RCL Ø2
12 *
13 "FPRO = "
14 XEQ "AP"
15 RTN
16 LBL "SKPRO"
17 "NS H/D"
18 PROMPT
19 STO 15
20 *
21 RCL Ø4
22 *
23 "SPRO = "
24 XEQ "AP"
25 "NT H/D"
26 PROMPT
27 STO 31
28 *
29 RCL Ø6
30 *
31 "TPRO = "
32 XEQ "AP"
33 +
34 "S + TPRO = "
35 XEQ "AP"
36 RTN
37 LBL "TRPRO"
38 "NTR H/D"
39 PROMPT
40 STO 18
41 ENTER↑
42 RCL Z
43 STO 33
44 X<>Y
45 *
46 LASTX
47 RCL Ø9
48 *
49 RCL 22
50 /
51 LASTX
52 X<>Y
53 INT
54 *
55 RCL 33
56 *
57 "TRPRO = "
58 XEQ "AP"
59 RTN
60 LBL "FCOSTS"
61 "FELL COSTS"
62 XEQ "Z5"
63 STO 25
64 "SAPCOSTS"
65 PROMPT
66 STO 26
67 RTN
68 LBL "SCOSTS"
69 "SKID COSTS"
70 XEQ "Z5"
71 STO 23
72 "SOPCOSTS"
73 PROMPT
74 STO 24
75 "TRACTOR COSTS"
76 XEQ "Z5"
77 STO Ø8
78 "TOPCOSTS"
79 PROMPT
80 STO 16
81 RTN
82 LBL "LCOST"
83 "LOAD COSTS"
84 XEQ "Z5"
85 STO 32
86 "LOPCOSTS"
87 PROMPT
88 STO 27
89 RTN
90 LBL TRCOSTS"
91 "TRUCK COSTS"
92 XEQ "Z5"
93 STO 28
94 "TROPCOSTS"
95 PROMPT
96 STO 3Ø
97 RTN
98 LBL "Z5"
99 AVIEW
100 Ø
101 STO ØØ
102 XEQ "OWN1"
103 XEQ "LAB1"
104 RCL ØØ
105 RTN
106 LBL "OWN1"
107 "VC VS"
108 PROMPT
109 X = Y?
110 RTN
111 -
112 STO 29
113 LASTX
114 "RI RM"
115 PROMPT
116 +
117 *
118 LASTX
119 "N"
120 PROMPT
121 ST/ 29
122 1
123 +
124 *
125 2
126 /
127 1
128 +
129 "RR"
130 PROMPT
131 +
132 ST * 29
133 X<>Y
134 ST + 29
135 "HRS PER YR"
136 PROMPT
137 ST/29
138 "NO OF PCS"
139 PROMPT
140 ST * 29
141 RCL 29
142 ST + ØØ
143 Ø
144 STO 29
145 GTO "OWN1"
146 LBL "LAB1"
147 "NO RATE"
148 PROMPT
149 X = Ø?
150 GTO "LAB2"
151 *
152 ST + 29
153 GTO "LAB1"
154 LBL "LAB2"
```

```
155 "RB RO"
156 PROMPT
157 1
158 +
159 X<>Y
160 1
161 +
162 *
163 RCL 29
164 *
165 ST+ 00
166 RTN
167 LBL "ACOST"
168 "AC PRO"
169 PROMPT
170 STO 00
171 FC? 01
172 GTO "Z1"
173 RCL 25
174 RCL 17
175 *
176 RCL 00
177 /
178 RCL 26
179 RCL 01
180 /
181 +
182 GTO "Z3"
183 LBL "Z1"
184 "FCOST"
185 PROMPT
186 LBL "Z3"
187 STO 29
188 "FELL="
189 XEQ "AP"
190 RCL 15
191 X=0?
192 GTO "Z2"
193 RCL 23
194 *
195 RCL 00
196 /
197 RCL 24
198 RCL 03
199 /
200 +
201 LBL "Z2"
202 RCL 31
203 X=0?
204 GTO "Z4"
205 RCL 08
206 *
207 RCL 00
208 /
209 RCL 16
210 RCL 05
211 /
212 +
213 LBL "Z4"
214 +
215 "SKID="
216 XEQ "AP"
217 RCL 29
218 +
219 RCL 32
220 8
221 *
222 RCL 00
223 /
224 RCL 27
225 RCL 07
226 /
227 +
228 "LOAD="
229 XEQ "AP"
230 +
231 RCL 28
232 RCL 18
233 *
234 RCL 00
235 /
236 RCL 30
237 RCL 10
238 /
239 +
240 "TRUCK="
241 XEQ "AP"
242 +
243 "TOTAL="
244 XEQ "AP"
245 STOP
246 LBL "FELL"
247 "BDH H"
248 PROMPT
249 STO 12
250 RDN
251 STO 11
252 "V1 V2"
253 PROMPT
254 STO 14
255 RDN
256 STO 13
257 CF 01
258 RCL 11
259 .3184
260 *
261 RCL 12
262 .4719
263 *
264 +
265 3.0349
266 -
267 STO 01
268 2.5
269 +
270 "WT"
271 PROMPT
272 +
273 STO 19
274 "$ PER HR?"
275 PROMPT
276 X≠0?
277 XEQ "AI"
278 RCL 19
279 1/X
280 STO 02
281 RCL 11
282 .24405
283 *
284 RCL 12
285 1.71424
286 *
287 +
288 5.24374
289 -
290 ST+ 01
291 RCL 01
292 1/X
293 STO 01
294 RCL 13
295 60
296 *
297 ST* 01
298 ST* 02
299 "END FELL"
300 AVIEW
301 RTN
302 LBL "SKID"
303 "D S/S S/T"
304 PROMPT
305 STO 21
306 RDN
307 STO 20
308 RDN
309 STO 19
310 .003
311 *
312 2.18224
313 +
314 STO 03
315 3.15239
316 +
317 STO 05
318 RCL 20
319 XEQ "BI"
320 ST+ 03
321 RCL 21
322 XEQ "BI"
323 ST+ 05
324 "LEVEL?"
325 PROMPT
326 X=0?
327 GTO "DI"
328 .98651
329 ST+ 03
330 ST+ 05
331 GTO "FI"
332 LBL "DI"
333 "UPHILL?"
334 PROMPT
335 X=0?
336 GTO "FI"
337 1.4376
338 ST+ 03
339 ST+ 05
340 LBL "FI"
341 "BUNCH?"
342 PROMPT
343 X≠0?
344 XEQ "GI"
345 "DT"
346 PROMPT
347 ENTER↑
348 ENTER↑
349 RCL 03
350 +
351 1/X
352 STO 04
353 X<>Y
354 RCL 05
355 +
356 1/X
357 STO 06
358 RCL 03
359 1/X
360 STO 03
361 RCL 05
362 1/X
363 STO 05
364 RCL 21
365 RCL 13
366 60
367 *
368 *
369 ST*05
370 ST*06
371 LASTX
372 RCL 20
373 *
374 ST*04
375 ST*03
376 "SA"
377 PROMPT
378 ST*04
379 ST*06
380 "END SKID"
381 AVIEW
382 RTN
383 LBL "TRUCK"
384 "CAP"
385 PROMPT
386 STO 22
387 RCL 14
388 /
389 1.03
390 *
391 4.6
392 +
393 STO 07
394 0
395 STO 10
396 "D1 D2"
397 PROMPT
398 X≠0?
399 XEQ "AT"
400 X<>Y
401 X≠0?
402 XEQ "BT"
403 "D3 D4"
404 PROMPT
405 X≠0?
406 XEQ "CT"
407 X<>Y
408 X≠0?
409 XEQ "DT"
410 "TU TD"
411 PROMPT
412 +
413 RCL 07
414 +
415 RCL 10
416 +
417 1/X
418 STO 09
419 RCL 07
420 1/X
421 STO 07
422 RCL 10
423 1/X
424 STO 10
425 RCL 22
426 60
427 *
428 ST*07
429 ST*10
430 "TA"
431 PROMPT
432 *
433 ST*09
434 "END TRUCK"
435 AVIEW
436 RTN
437 LBL "AT"
438 5
439 *
440 3.1
441 +
442 ST+ 10
443 RTN
444 LBL "BT"
445 3.175
446 *
447 11.125
448 +
449 ST+ 10
450 RTN
451 LBL "CT"
452 19.64
453 *
454 5.96
455 +
456 ST+ 10
457 RTN
458 LBL "DT"
459 7.742
460 *
461 7.68
462 +
463 ST+ 10
464 RTN
465 LBL "AI"
466 SF 01
467 X<>Y
468 RCL 11
469 .0628
470 *
471 .484
472 -
473 ST+ 01
474 +
475 1
476 +
477 STO 19
478 RTN
479 LBL "BI"
480 RCL 13
481 1.42
482 *
483 1.924
484 +
485 *
486 RTN
487 LBL "GI"
488 RCL 20
489 XEQ "HI"
490 ST- 03
491 RCL 21
492 XEQ "HI"
493 ST- 05
494 RTN
495 LBL "HI"
496 1.395
497 *
498 .32
499 -
500 RTN
501 LBL "UPRO"
502 "UFPRO="
503 ARCL 02
504 XEQ "BP"
505 "USPRO="
506 ARCL 04
507 XEQ "BP"
508 "UTPRO="
509 ARCL 06
510 XEQ "BP"
511 "ULPRO="
512 ARCL 07
513 XEQ "BP"
514 "UTRPRO="
515 ARCL 09
516 AVIEW
517 RTN
518 LBL "AP"
519 ARCL X
520 LBL "BP"
521 AVIEW
522 STOP
523 RTN
524 END.
```

Appendix C

Nomenclature for Keys and Displays

USER—ready for use of reassigned keys (M bf/Scheduled hours)
PRGM—program
ALPHA—alphabet designates
DBH H—diameter at breast height (inches)—height of the trees (no. of 16-ft. logs).
R/S—run/stop, use for data entry
V1—average volume per tree (M bf)
V2—average volume per log (M bf)
WT—average walking time from tree felled to the next tree (minutes)
$ PER HR?—salary at hourly rate, yes or no
END FELL—input for felling completed
D S/S S/T
 D—average skidding distance (feet)
 S/S—number of stems pulled by the rubber-tired skidder
 S/T—number of stems pulled by crawler-tractor
LEVEL?—yes or no
UPHILL?—yes or no
BUNCH?—yes or no
DT—delay time per turn (minutes)
SA—machine availability
CAP—average truck capacity (M bf)
D1—distance of hauling in miles on paved road (2 lane)
D2—distance of hauling in miles on paved road (1 lane)
D3—distance of hauling in miles on a one-lane gravelled road
D4—distance of hauling in miles on a woods road
TU TD—truck unloading time (minutes)—truck delay time (minutes)
TA—truck availability
END TRUCK—input for trucking completed
UFPRO—unit felling production (M bf/Scheduled hour)
USPRO—unit rubber-tired skidding production (M bf/Scheduled hour)
UTPRO—unit tractor skidding production (M bf/Scheduled hour)
ULPRO—unit loading production (M bf/Scheduled hour)
UTRPRO—unit trucking production M bf/Scheduled hour)
NF H/D—number of fellers and the hours per day that they work
FPRO—felling production per day (M bf)
NS H/D—number of rubber-tired skidding units and the hours per day they work
SPRO—skidding production per day with rubber-tired skidders (M bf)
NT H/D—number of units of skidding tractors and the hours per day they work
TPRO—skidding production per day with tractors (M bf)
S + TPRO—skidding production per day (M bf)
FELL COSTS
 VC—cost value ($)
 VS—salvage value ($)
RI RM—interest rate—maintenance rate (based on average investment)
N—number of years of useful life
RR—rate of repairs (based on depreciation)
HRS PER YR—average number of hours of use per year
NO OF PCS—number of pieces
VC VS—(the second time) starts data over for next category as equipment variations
NO RATE—number of workers—rate of pay per hour
RB RO—percentage of wages paid FOR BENEFITS—percentage of wages paid for overhead
SAPCOSTS—saw operating costs ($/hour)
SKID COSTS
 VC—cost value ($)
 VS—salvage value ($)
SOPCOSTS—skidder operating costs ($/hour)
TRACTORCOSTS
 VC—cost value ($)
 VS—salvage value ($)
NO RATE—number of operators—hourly rate
RB RO—percentage of wages paid for benefits—percentage of wages paid for overhead
TOPCOSTS—tractor operating costs ($/hour)
LOAD COSTS
 VC—cost value ($)
 VS—salvage cost ($)
TROPCOSTS—truck operating costs ($/hour)
AC PRO—actual production (M bf/day)
FELL—actual felling costs ($/M bf)
SKID—skidding costs ($/M bf)
LOAD—loading costs ($/M bf)
TRUCK—trucking costs ($/M bf)
TOTAL—total logging costs ($/M bf)

Phillips, Ross A.; Peters, Penn A.; Falk, Gary D. The weak link HP-41C hand-held calculator program. Broomall, PA: Northeast. For. Exp. Stn.; 1982; USDA For. Serv. Res. Pap. NE-510. 12 p.

Describes a hand-held calculator program (HP-41C) that quickly analyzes a system for logging production and costs. The program models conventional chain saw, skidder, loader, and tandem-axle truck operations in eastern mountain areas. The program calculates production of each function of the logging system from user-supplied input. System production equals the lowest production of any function—the weak link. Costs of each function are calculated to obtain logging costs in dollars per M bf.

Keywords: Harvesting costs, logging, hand-held calculator, timber production, forest engineering.

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