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L-O-S-T: Logging Optimization Selection Technique

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SUMMARY

L-O-S-T is a FORTRAN computer program that can be used to quantify, analyze, and improve user selected harvesting methods. Harvesting times and costs are computed for road construction, landing construction, system move between landings, skidding, and trucking. Nonlinear harvesting relationships, irregular boundary shapes, nonuniform timber densities, unequal distances between multiple landings, variations in road construction conditions, changes in trucking speeds, and harvesting restrictions (environmental, physical, and time) can be analyzed. A linear programming formulation utilizing the relationships among marginal analysis, isoquants, and the harvesting methods is used to estimate and select the harvesting procedure having maximum profits.

ACKNOWLEDGMENTS

The linear programming algorithm used in L-O-S-T is a modification of one developed by Dr. A. Ravindran, Chairman and Professor, Department of Industrial Engineering, University of Oklahoma, Norman, Oklahoma. The input-output format modifications to Dr. Ravindran's program were made by E. Wade Culver, a computer engineer employed by the U. S. Forest Service at Auburn, Alabama, at the time of this study.

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INTRODUCTION

An age-old problem for timber harvesters is that of selecting the location for roads and landings that will maximize profits. This complex problem is partially due to: 1) nonlinear harvesting relationships, 2) non-uniform terrain and timber characteristics, 3) irregu lar tract boundaries with interior obstacles, and 4) the lack of a ***general*** mathematical expression describing total costs as a function of road densities, landing spacings, skidding distances, and equipment mixes.

Existing Solution Techniques

One of the earliest mathematical attempts to minimize harvesting costs was by Matthews (1942). To simplify the problem, he assumed: 1) the forest boundary could be approximated by simple geometric shapes, 2) linear cost relationships, 3) equal spacings between multiple landings, and 4) uniform slopes and timber densities. Using an indirect method, Matthews determined the optimum location of roads and landings by using calculus to obtain the minimum of unconstrained equations. Peters (1978) extended this approach by developing a direct method to determine optimum location of roads and landings. Although Peters used most of Matthews' assumptions, he included landing costs and used a mathematically accurate method developed by Suddarth (1952) for determining average skidding distance. Corcoran and Sammis (1975) developed a computer program to solve the road and landing spacing equations developed by Matthews. Their computer program solves two equations in two unknowns through a heuristically iterative procedure.

Operations research techniques were used very early by Lussier (1960, 1961) to minimize harvesting costs. He developed equations useful in determining the optimum number of landings, the distance between skid roads, and optimum skid road standards. Lussier also discussed several limitations on using a strictly mathematical approach and in making simplified assumptions in solving harvesting problems.

Gibson and Egging (1973) developed a location-allocation model for determining the optimal number and location of landings when using rubber-tired skidders. A truncated enumeration algorithm was used in the allocation phase to search systematically for a local optimum solution. Dynamic programming and a branch and bound methodology were used to find the global optimal solution.

Dykstra (1976) used mathematical and heuristic programming to determine the design of individual cutting units and the assignment of specific logging equipment to each cutting unit. He assumed that timber within each "type island" was homogenous and uniformly distributed and that only cable systems would be used to harvest timber on clearcuts. He also developed a digital model to portray topography, timber conditions, and harvest restrictions.

Carter et al. (1973) developed a computer model to determine the optimum spacings of roads and landings. Their work involved minimizing harvesting costs in the Rocky Mountain area where timber was accessible either by contour work-roads or switchbacks. An iteration solution technique was used to find simultaneous zero points of the partial derivatives of the road and landing spacing equations.

Several simulation models have been developed to analyze timber harvesting problems. However, most simulation models consider only a single landing and are not specifically developed to determine the optimum location of roads and landings. Several simulation models [Forest Harvesting Simulation Model (FHSM), Harvesting System Simulator (HSS), Simulation Applied to Logging Systems (SAPLOS), and Timber Harvesting and Transport Simulator (THATS)] were evaluated by Goulet et al. (1980).

Weintraub and Navon (1976) developed a mixed integer linear programming model to maximize dis-

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counted revenues from timber sales. Road construction and maintenance, timber management, and transportation were considered. The model was developed as a tool for decision in long range forest planning. Constraints were allowed on available capital, quantity of timber harvested, haul capacity of each road, and stand access. Kirby (1974) and Newnham (1975) also developed mathematical programming models useful in the long-range planning of harvesting operations.

Objectives

Existing techniques have provided useful insights into optimum timber harvesting strategies. For harvesting specific tracts of timber by ground-based skidding systems, these models are limited. Realistic harvesting costs often are not computed because overly simplified assumptions are made concerning stand boundary shapes, slopes, timber characteristics, and harvesting methods. The objectives of this study were to: 1) develop a computer program capable of determining realistic harvesting times and costs for highly individualistic conditions, and 2) utilize these harvesting times and costs, as well as harvesting constraints, in a unique linear programming formulation to obtain maximum profits. This FORTRAN computer model is titled L-O-S-T, an acronym for logging optimization selection technique.

HARVESTING FUNCTIONS OPTIMIZED

Although the methodology used to compute harvesting times and the linear programming formulation are *general*, the equations used to compute harvesting times are based on data collected in the Tennessee Valley Region (fig. 1). Harvesting times and costs are only calculated for road construction, landing construction, system move between landings, skidding, and trucking (fig. 2). Their relationships to selecting harvesting methods and the linear programming formulation are discussed in later sections. Costs are not calculated for felling, bucking, and loading (figs. 3 and 4) because those costs are not *assumed* to be significantly affected by the locations of roads and landings. The assumed general relationships among various harvesting activities and harvesting costs optimizations are shown in figure 5.

Road Construction

Construction of truck roads within the harvest boundary reduces skidding costs, but increases road construction, landing construction, system move, and trucking costs. In L-O-S-T, a road is considered as a low volume, temporary structure constructed solely for removing trees. If a high volume road is constructed with a design standard or life expectancy greater than that needed for timber harvesting, then the cost of the road must be adjusted to reflect only timber harvesting. The equation (Al, appendix 1) used to compute road construction times was developed by Koger (1978) from data collected in the Tennessee Valley Region.

Due to irregular terrain, construction conditions are seldom uniform over the entire road network. In order to determine more accurately construction costs, the road can be divided into short segments. These segments reflect differences in bank cubic yards, road slope (grade), or construction problems caused by rock or dense timber.

Although the number of bank cubic yards removed for making the roadbed is a variable, it does not have to be computed by the user. However, the user must supply roadbed width, side-hill slope, cut-slope ratio, and fill-slope ratio. This information is used in an equation reported by Bowman et al. (1975) to calculate bank cubic yards. Another variable, the number of acres in the road right-of-way, is also calculated for the user.

The construction of skid trails or skid roads for use by rubber-tired skidders is not computed in L-O-S-T. Skid road costs are assumed to be independent of the locations of truck roads and landings.

Landing Construction and System Move

Landings are usually constructed in conjunction with the road system, primarily as storage and loading areas for the skidded trees. Increasing landings decreases skidding costs, but increases system move, landing construction, and trucking costs. The equation used to compute landing construction times is a modification of the road construction equation (Al, appendix 1). The landing size in acres is converted to an "equivalent" road length based on an assumed cleared road width of 26.7 feet. An average cleared road width of 26.7 feet was observed in a study of logging roads in the Tennessee Valley Region (Koger 1978). A road construction condition factor of 3,000 is used (variable X6). In addition, the depth of the cut to level the landing site is assumed to be uniform across the landing area.

System move costs are those involved in moving equipment such as loaders, crawler tractors used for decking or landing maintenance, and shop trucks to the next landing. These costs are related to the distance and road condition between landings, the amount and type of equipment, and the hourly cost of the equipment and associated labor. Skidders may be included if they travel unloaded to the next landing site. Haul trucks are not included. If only one landing is used, system move costs are assumed to be zero. Move-in costs are not considered because they are

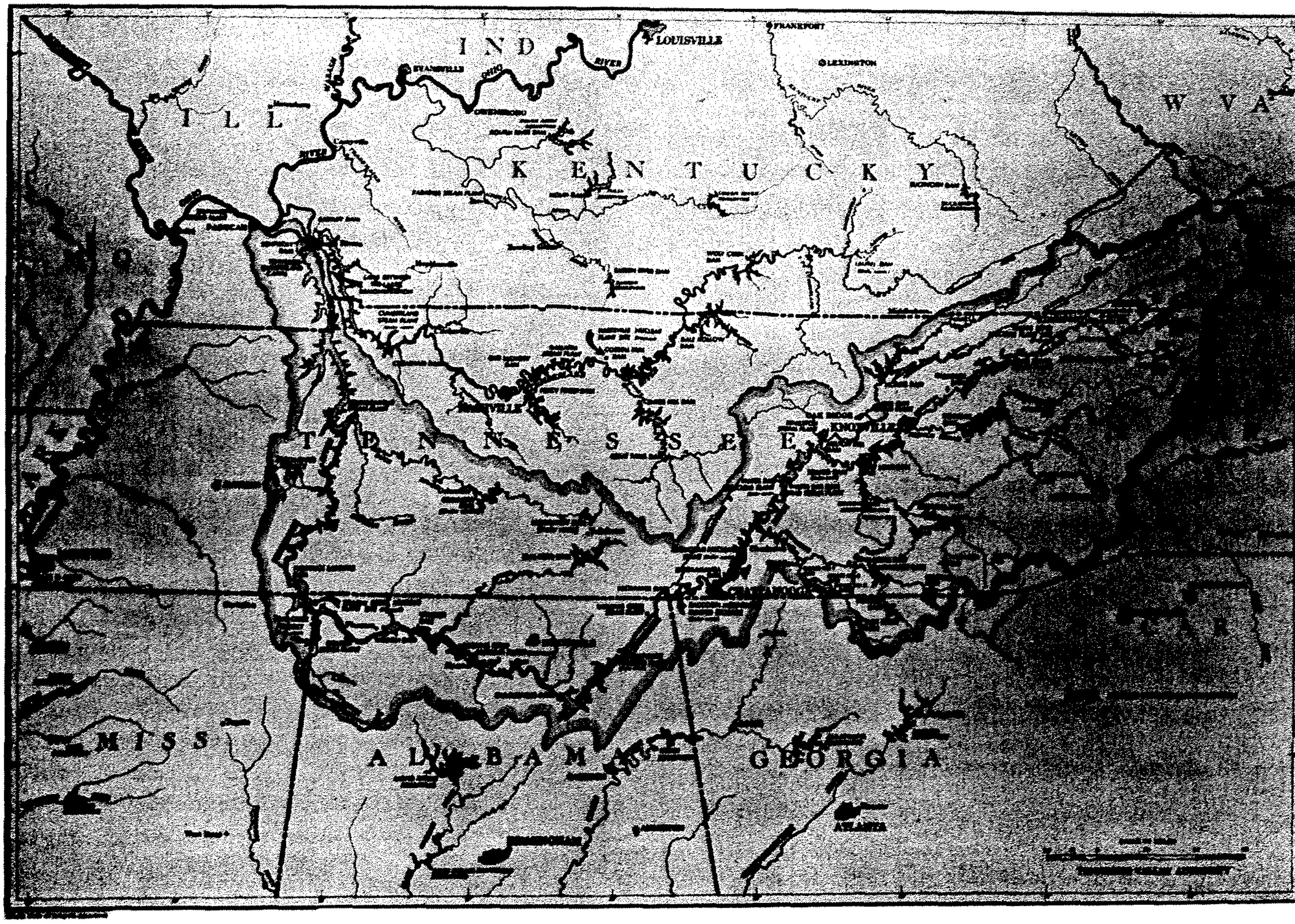

Figure 1.-The *Tennessee Valley Region (Tennessee, Kentucky, Virginia, North Carolina, Georgia, Alabama,* & **Mississippi).**

assumed to be approximately constant with whatever the locations of roads and landings.

In the linear programming formulation, landing construction and system move times are considered together. Since a relationship exists between these two costs, it is perhaps easier to think of them jointly rather than separately. Equation A5 (appendix 1) is used to compute a weighted time for landing construction and system move between landings.

Skidding

Skidding costs depend largely on skidding distance, which can be controlled through the locations of roads and landings. Skidding costs decrease as the density of roads and landings increases. The equation (A3, appendix 1) used to compute skidding times was developed by Koger (1976) for articulated, four-wheel drive, rubber-tired skidders operating in the Tennessee Valley Region. The range of observed volumes skidded in this region is shown in table 1 (appendix 1). Techniques available to compute average skidding distance are described in appendix 2. The differences among average skidding distance, the distance actually traveled by the skidder, and fixed skidding distance are also discussed.

Trucking

Trucking over roads within the harvest boundary reduces skidding costs but increases trucking, road construction, landing construction, and system move costs. The trucking speeds and load volumes shown in tables 2 – 4 (appendix 1) are based on data collected **in** the Tennessee Valley Region by Koger (1981). With respect to the optimum location of roads and landings, it is not necessary to compute trucking costs from the mill to the edge of the harvest boundary. This distance remains constant and is not affected by the road density or trucking pattern inside the harvest boundary. However, trucking costs are computed from each lauding to the mill or delivery point because calculating these costs: 1) does not change the optimum location of roads and landings, 2) may alert the user to consider other routes from the mill to the harvest boundary, and 3) provides the user with an estimate of total trucking costs.

Figure *2.-Truck road construction, system moue between landings, skidding, trucking, and landing construction times are computed in L-O-S-T.*

SELECTING HARVESTING METHODS

Method Selection

The user must determine either two, three, or four different-but realistic-harvesting methods. These different methods can be viewed as harvesting or transportation plans. As a rule this requires drawing the boundary, stand densities, harvesting restrictions, road and landing locations, and skidding patterns on a topographic map. The methods should be selected so that road density (or road length) is at a minimum for the first method and at a maximum for the last method. Intermediate methods should be between these limits. Truck roads can be divided into segments to reflect differences in sidehill slope, road slope (grade), road width, or other construction factors. The size, construction condition, and distance from the harvest boundary is needed for each landing. The skidding pattern must be determined for each area and all landings. An area is a subdivision of a stand and its boundary is used in determining average skidding distance. Areas should be numbered consecutively within a stand and numbered so that no two areas have the same area number. An area can be subdivided into two or more new areas to reflect changes in skidding patterns among landings for different methods. The complexity of harvesting problems and the level of detail or realism required by thi user is reflected in the number of areas selected.

Types of Harvesting Plans

L-O-S-T is capable of analyzing most ground-based plans including: 1) single road extension, 2) variable landing spacings along a fixed road length, 3) parallel roads, 4) multiple contour roads, 5) spur road extensions from major roads, and 6) climbing roads with switchbacks. The only requirement for analyzing any harvesting plan is that some relationship of road

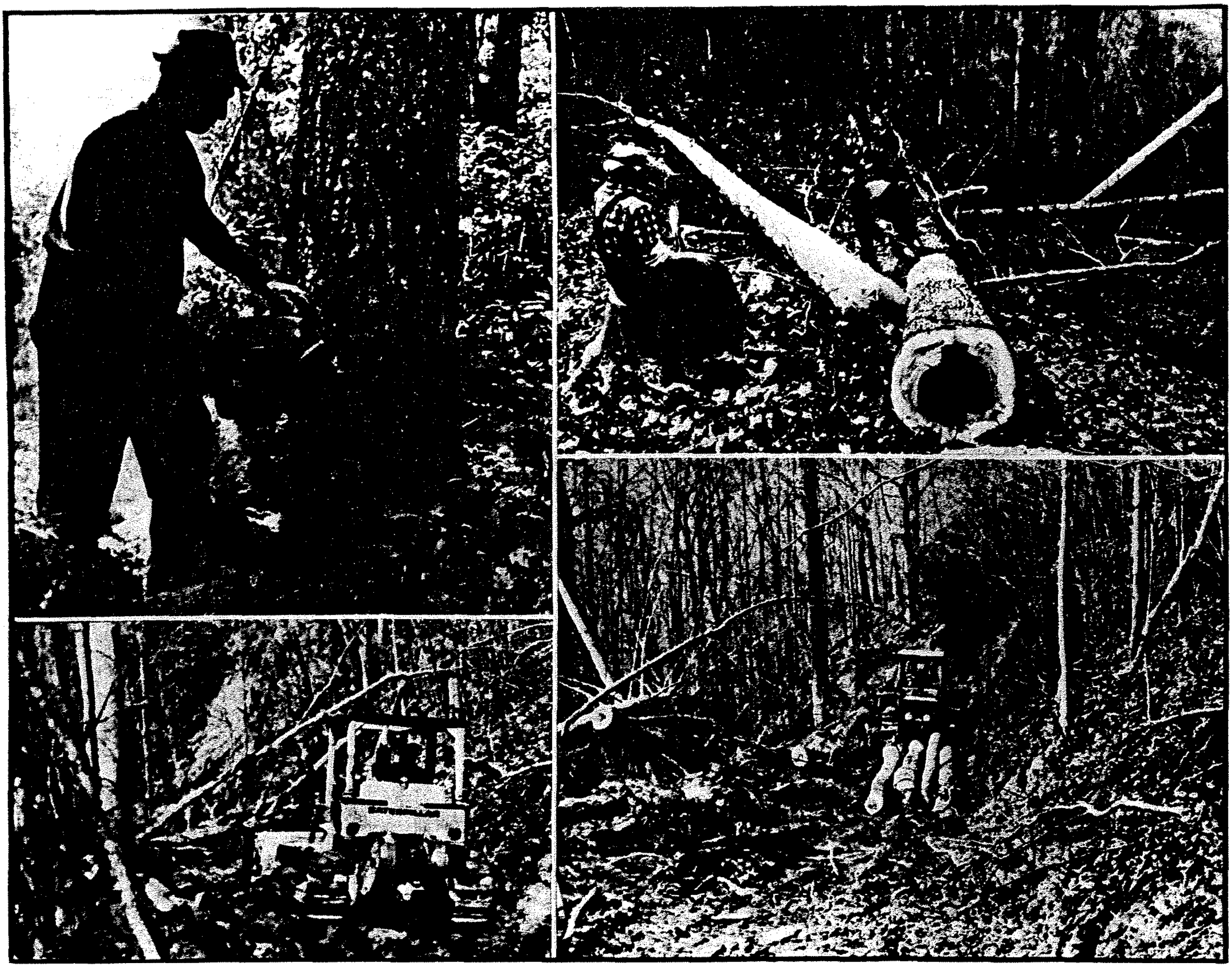

Figure 3.—*Felling, bucking, skid rood construction, and bunching times are not computed in L-O-S-T.*

length and skidding exists between adjacent harvesting methods: From a silviculture perspective these harvesting plans could be for individual tree selection, group selection, diameter limit, financial maturity, or clear cuts. Once a cutting practice has been selected for an area in one method, it must remain the same in all the remaining methods. More than one different cutting practice may be used within a stand or harvest boundary.

OPTIMIZATION METHODOLOGY

Linear Programming Formulation

After the hours required for road construction, landing construction, system move between landings, skidding, and trucking have been calculated for each method, they are utilized in a linear programming formulation (equations 1 – 6). The formulation determines the proportion (λ) of each method that should be used. The formulation used in L-O-S-T is a slight modification of McCarl's (1979) and is also very similar *to* those developed by Allen (1956) and Chiang (1974).

$$
\begin{array}{llll}
\text{Maximize:} & Z = PQ_0 - \Sigma C_i H_i & & (1) \\
\text{Subject to:} & Q_0 - \Sigma Q_m \lambda_m & \leq 0 & (2) \\
 & \Sigma X_{im} \lambda_m - H_i & \leq 0 & (3) \\
 & Q_0 & = Q_m & (4) \\
 & \Sigma \lambda_m & = 1 & (5) \\
 & H_i & \leq b_i & (6) \\
 & Q_0, Q_m, \lambda_m, H_i \geq 0 & &
\end{array}
$$

where: Z = objective function

P = delivered price of the harvested timber (ie. \$/ 1,000 board feet)

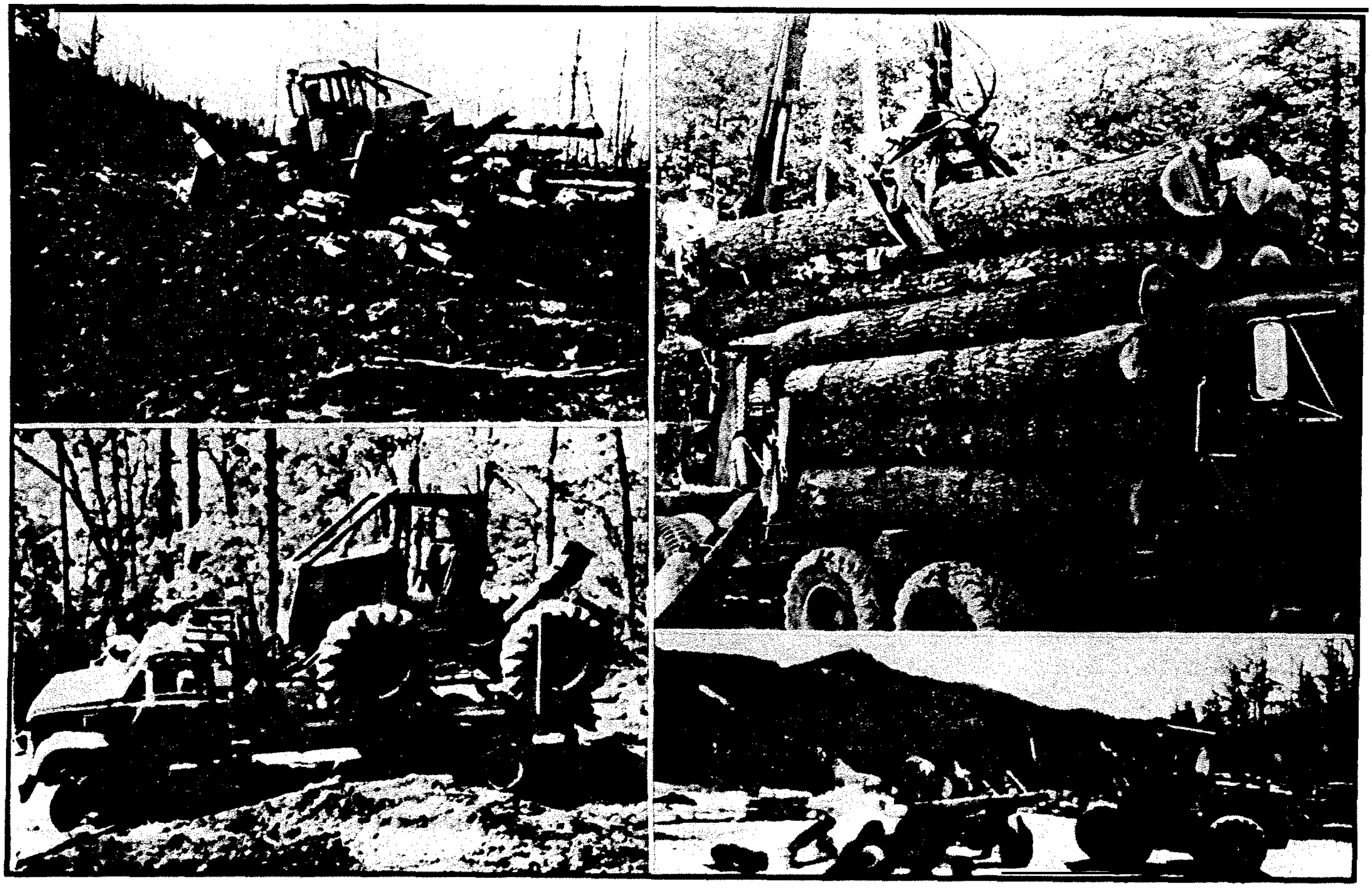

Figure &-Decking, loading, move-in, and unloading *times are not computed in LO-S-T.*

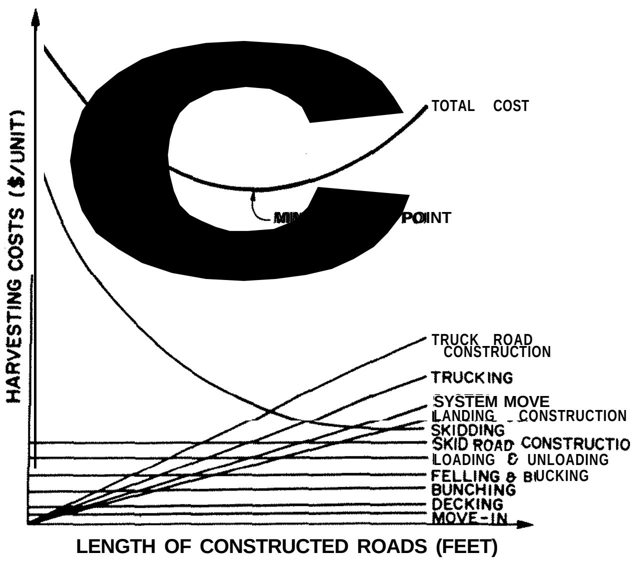

Figure *B.-Assumed harvest cost relationships with respect to the optimum location of roads and landings (Note: fixed costs lines are in an arbitrary order).*

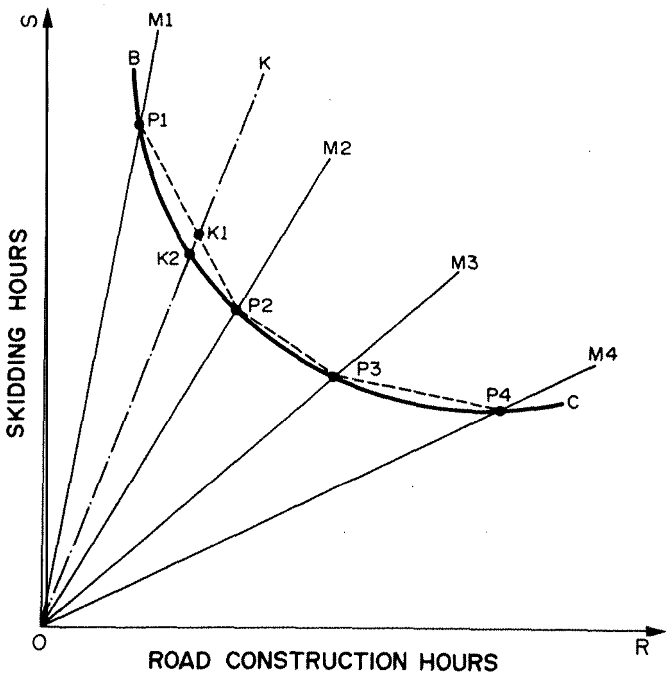

Figure C-Relationships among isoquants, activity rays, and harvesting functions.

Q_0 = volume of timber harvested (ie. board feet)
C_i = hourly equipment and labor cost for the i th activity (i = 1 for road construction, i = 2 for landing construction and system move, i= 3 for skidding, and i = 4 for trucking
H_i = the total number of hours of the i th activity used by all harvesting methods
λ_m = the proportion of the m th method used to harvest the total volume of timber (a decision variable)
X_{im}= the number of hours for the i th harvesting activity of the m th method
b_i = maximum number of hours allowed for the i th harvesting activity

Formulation Explanation

The relationships among the formulation (equations 1 - 6), harvesting times, and harvesting methods are shown in figure 6. Assume that a boundary of timber can be harvested by one of four methods (Ml, M2, M3, or M4). For simplicity in graphing, only the harvesting activities of skidding (the hours required are mapped on the OS axis) and road construction (the hours required are mapped on the OR axis) will be considered. The volume of timber harvested is constant and represented by the isoquant BC, Fewer hours of skidding are required as the hours of road construction increases. The harvesting methods can be considered as activity rays (OM1, OM2, OM3, & OM4) with four activity vectors:

$$P1 = \begin{bmatrix} S1 \\ R1 \end{bmatrix} \quad P2 = \begin{bmatrix} S2 \\ R2 \end{bmatrix} \quad P3 = \begin{bmatrix} S3 \\ R3 \end{bmatrix} \quad P4 = \begin{bmatrix} S4 \\ R4 \end{bmatrix}.$$

Each activity vector shows a distinct input ratio capable of yielding a constant **volume** of harvested timber (isoquant BC). Thus, **P1** indicates that method 1 (Ml) is used to harvest all of the timber. This formulation assumes that it is **also** possible to harvest timber in various convex combinations such as: **(¼P1 + ¾P2)**.

This means that a new method can be determined which uses ¼ of the skidding hours of method 1, plus ¾ of the skidding hours of method 2, plus ¼ of the road construction hours of method 1, **plus ¾ of the** road construction hours for method 2. Graphically, this means that the ratios for the combined processes must lie on the dashed **line** segments **(P1P2, P2P3, P3P4)**. Assume that the optimum combination of skidding and road construction hours is at point **K1** on activity ray OK. Due to the convex nature of the production function represented by the isoquant BC, point **K1** is not on BC. The difference between **K1** and K2 on the activity ray OK represents the error involved in attempting to solve a nonlinear convex production function with a linear approximation.

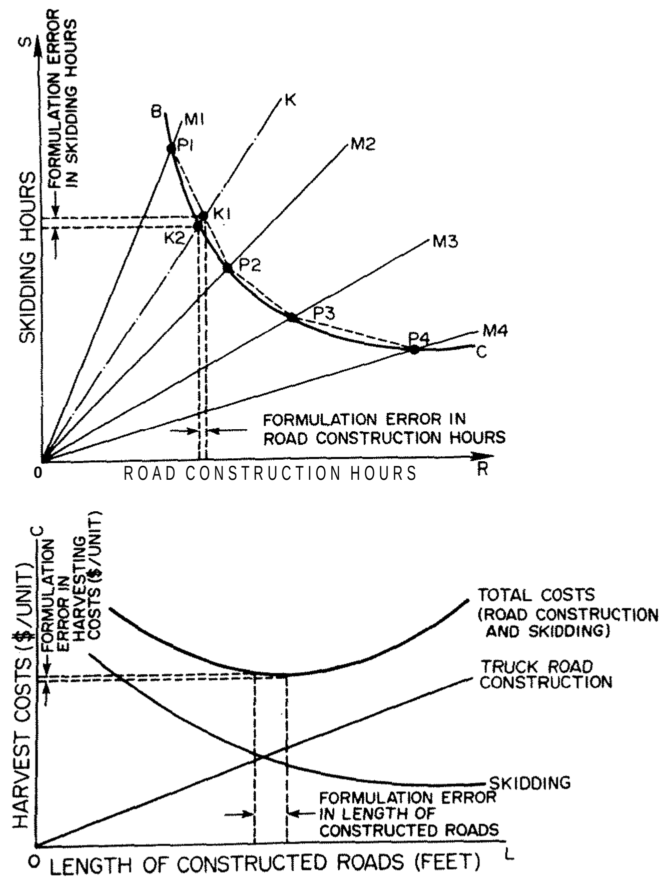

Figure 7.—*Error relationships involved in using the formulation.*

This error is not considered to be significant; its relationships to the formulation, harvesting methods, and harvesting costs are shown in figure ‘7. The formulation will pick. only one method or a linear convex combination of adjacent methods (Allen 1956; Chiang 1974).

The assumptions of linear ‘programming **(additivity**, linearity, divisibility, finiteness, and single-value expectations) are basically those used in the traditional **marginal** analysis of the firm. For timber harvesting, a specific method has a constant and linear proportionality between hours worked and volume harvested. Fractional hours worked can result in a fractional volume harvested. Finiteness means there are limits to the number of hours permitted to harvest a boundary of timber. The single-value expectation assumption assumes realistically that the quantity of timber harvested and its selling price is known. Another basic assumption is that the volume of timber harvested is not dependent on the harvesting method. This results in a fixed output independent of the number of hours required for road construction, landing construction, system move, skidding, and trucking.

HARVESTING EXAMPLE PROBLEM

Problem Description

An example problem has been developed to help illustrate the procedures used to select different harvesting methods, data input requirements, linear programming formulation, and program output. Specifically, the problem is to maximize profit by determining the least cost harvesting method for the boundary of timber shown in figure 8. The timber is to be harvested by a crawler tractor, two rubber-tired, cable skidders, and two trucks (table 5, appendix 3). Selected equipment weight and horsepower characteristics are given in appendix 4. The problem is sufficiently realistic to be interesting and complex'enough to prevent the formulation of a *general* mathematical expression that could be differentiated to obtain minimum costs. The complexity of the problem is increased by: 1) an irregular boundary, 2) nonuniform timber densities or timber stands (fig. 9), 3) elevation changes, 4) restrictions on streambed crossings, 5) unequal costs for different road segments and landings, 6) unequal distances between landings, 7) nonlinear skidding costs, 8) decreases in truck travel speeds as the length of the road constructed inside the harvest boundary increases, and 9) restrictions on the time permitted for road construction (120 hours) and skidding (600 hours).

Harvesting Methods for the Example Problem

For the first method, a woods road was constructed 350 feet inside the harvest boundary and one landing constructed at location A (fig. 10). All the areas were skidded to this landing. Compared to the other methods, this method minimizes costs for road construction, landing construction, trucking, and system move, but maximizes skidding costs. For the second method, a woods road was constructed 2,525 feet inside the harvest boundary and landings constructed at locations A and B (fig. 11). Areas 1, 3, and 4 were skidded to landing A and the remaining areas skidded to landing B. It is important to recognize that areas can be subdivided to reflect changes in skidding patterns for different methods. For example, area 2 used in method 1 was subdivided into areas 3 and 6 for method 2. Area 3 was skidded to landing A, but area 6 was skidded to landing B. For the third method, a woods road was constructed 3,875 feet inside the harvest boundary and landings constructed at locations A, B, and C (fig. 12). Areas 1, 3, and 4 were skidded to landing A and areas 5, 6, 7, 8, and 9 skidded to landing B. The remaining areas were skidded to landing C. For the fourth method, a woods road was constructed 6,775 feet inside the harvest boundary and landings constructed at locations A, B, C, and D (fig. 13). Areas 1, 3, and 4 were skidded to landing A; areas 5, 6, 7, 8, and 9 to landing B; areas 10, 11, 15, and 19 to landing C; and areas 16, 17, 20, 21, 22, and 23 to landing D. Area 18 in methods 1 – 3 was subdivided into areas 19 and 20 to reflect changes in skidding patterns for method 4. Compared to other methods, this method minimizes skidding costs, but maximizes road construction, landing construction, system move, and trucking costs. A summary of several calculated and assumed values for each of these methods is given in appendix 3 (tables 6-11).

Data Input

For each method selected, specific input information is required on road construction, landing construction, system move between landings, skidding, trucking, and equipment costs. Sixteen data "card

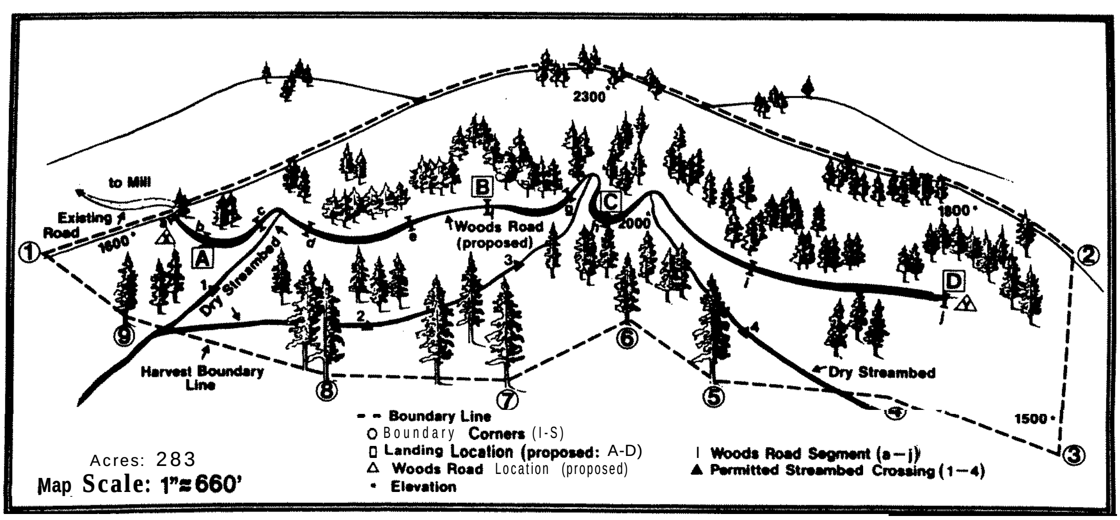

Figure &-Harvesting example problem.

types" are required for each analysis of a boundary of timber to be harvested. An additional card type is required if constraints are placed on the number of hours allowed for any of the pertinent harvesting activities. These different card types are described in detail in appendix 5. The complete input data used to analyze the hypothetical example is shown in appendix 6. The values shown for average skidding distance were based on the harvest patterns for the different areas and landing locations in figures 10 – 13. Average skidding distances were determined using a BASIC program written for use on an HP 9830A[1] calculator and HP 9864A digitizer.

Output Analysis

The computer output for the harvesting example problem is shown in appendix 7. The output consists of: 1) an echo check of the input data, 2) harvesting times and costs, and 3) the linear programming solution and sensivity analysis.

Road construction times and costs, the number of bank cubic yards, and acres cleared for the road-right-of-way are given for each segment. Road construction costs are: $170 for method 1 ($2,565 per mile); $1,061 for method 2 ($2,219 per mile): $1,625 for method 3 ($2,214 per mile); and $2,910 for method 4 ($2,268 per mile). The easiest way to modify road construction costs without changing the road design or road construction equipment characteristics is through the input variable ROADTY (card type 10, appendix 5). Although guidelines are provided for estimating ROADTY, a value should be selected that gives reasonable cost estimates based on the user's experience or modeling needs.

Landing construction and system move times and costs are computed for each landing. Landing construction costs are: $56.27 for method 1; $89.64 for method 2; $118.73 for method 3; and $150.83 for method 4. The simplest way to influence landing construction costs without changing the landing design or landing construction equipment characteristics is through the input variable EFFL (card type 12, appendix 5). System move costs are: $0.0 for method 1; $101.26 for method 2;.$192.39 for method 3; and $303.78 for method 4.

Skidding times and costs are computed for each skidder on each area and summarized by area, landing, and method. The number of cycles and average cycle time are also given. The skidding costs are: $28,769.13 for method 1; $18,076.16 for method 2; $15,471.31 for method 3; and $10,950.56 for method 4. The easiest way to modify skidding times without changing skidder characteristics, skid load volumes, or skidding distances is through the input variable, AD (card type 13, appendix 5).

In addition to skidding times and costs, average skidding distance, fixed skidding distance, and weighted actual travel skidding distances are summarized by landing and method. In most cases the greatest potential for reducing skidding times is through a reduction of average fixed skidding distance. In the harvesting example problem, average skidding distance only decreased from 686 feet for method 1 to 550 feet for method 4. However, average fixed skidding distance decreased form 4,296 feet for method 1 to 759 feat for method 4. This drastic reduction in average fixed skidding distance was largely responsible for skidding times decreasing from 659.75 hours for method 1 to 264.83 hours for method 4. Weighted average travel skidding distance is computed by mul-

[1]The use of trade or corporate names is for reader association and convenience. Such does not constitute an official evaluation, conclusion, recommendation, endorsement, or approval of any product or service to the exclusion of others which may be suitable.

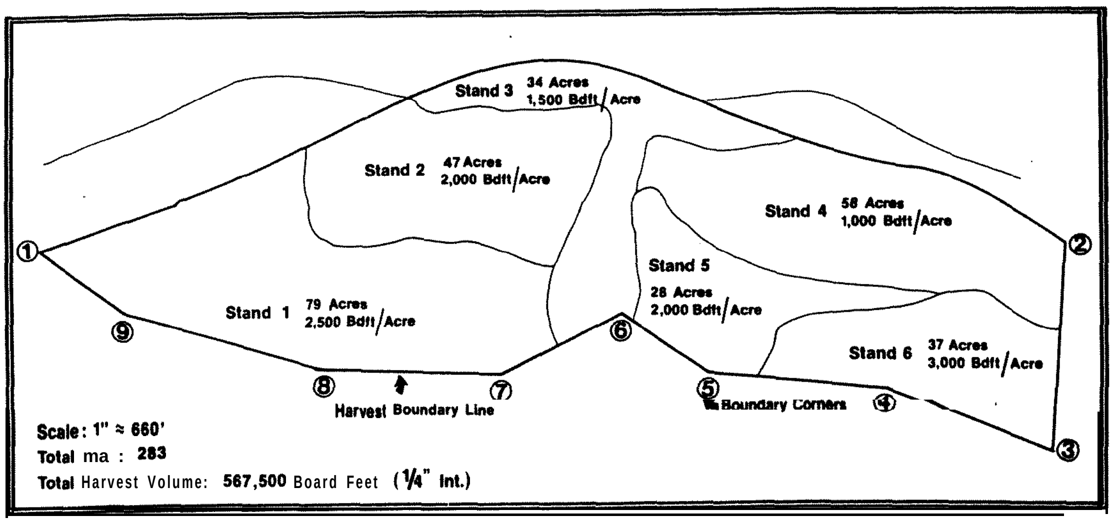

Figure O.-Stand densities and acres for the harvesting problem.

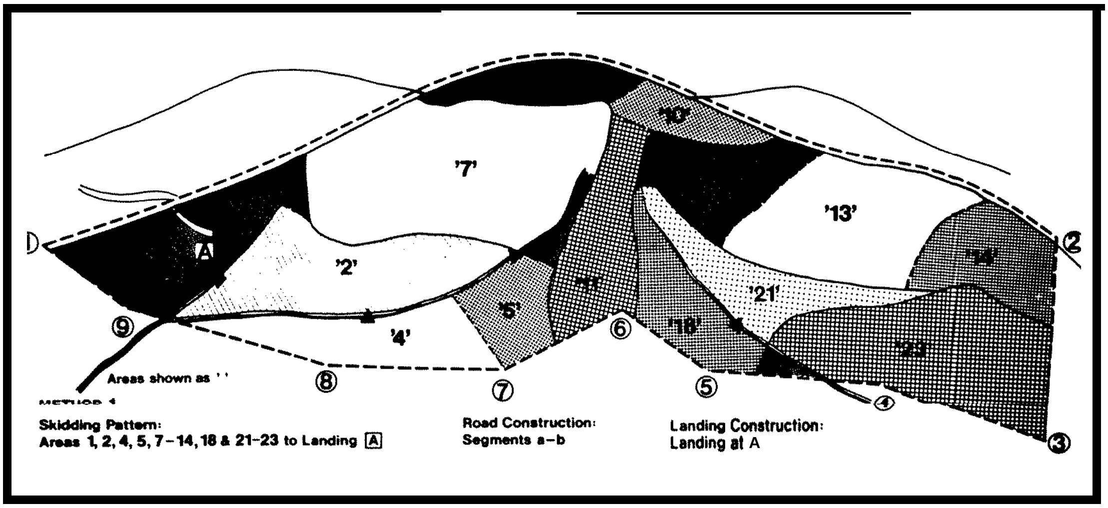

Figure 10.—*Road, landing,* **and area** *locations used in method 1.*

tiplying average skidding distance by the skidding correction factor for each area. This product is added to to the fixed skidding distance on each area and then multiplied by the volume for that area in order to obtain a weighted value.

The number of acres and volume of timber harvested for each method are provided as information and as checks on the accuracy of data input. The number of acres for each method must be the same and the volume harvested for each method must be the same. In this example, 283 acres and 567,500 board feet (¼ ″ Int.) were harvested for each method. The linear programming formulation requires that an equal volume of timber be harvested in each method.

Trucking times and costs are shown for each truck and are summarized by landing and method. In addition, cycle times and number of loads required for each truck are given. Trucking costs for each method are: $17,182.48 for method 1; $17,913.40 for method 2; $18,277.16 for method 3; and $18,774.91 for method 4. In this case the construction of four landings and 6,775 feet of woods roads only increased trucking costs by $1592.43.

A method summary giving the hours, costs per harvesting unit for each function, total costs, and total costs per harvesting unit is provided in the output. The total harvesting costs per thousand board feet (¼ ″ Int.) for road construction, landing construction and system move, skidding, and trucking are: $81.37 for method 1; $65.62 for method 2; $62.79 for method 3; and $58.31 for method 4. The hours required for each harvest function considered in L-O-S-T are shown in table I and are used to illustrate a numerical example of the linear programming formulation (equations 7 - 16). The formulation can also be seen in the output (appendix 7) as the first iteration of the linear programming tableaus.

Table *I.--Harvest hours for the four methods*

Harvest Function	Method 1 (hours)	Method 2 (hours)	Method 3 (hours)	Method4 (hours)
Road construction	7.86	49.07	75.12	134.65
Landing construction & system move	0.78	2.64	4.31	6.29
Skidding	695.75	437.15	374.16	264.83
Trucking	429.56	447.83	455.68	469.37

After 18 iterations the optimum linear programming solution consisted of 24 % of method 3 and 76%. of method 4. The optimum method (not a global optimum) used 120 hours of road construction, 5.8 hours of landing construction and system move, 292 hours of skidding, and 466 hours of trucking. The linear programming solution does not give the exact physical location of the roads, landings, and skidding patterns. However, the output Can be used to help locate the road, landings, and skidding patterns for a new method consisting of 24% of method 3 and 76% of method 4. Since 102.2 hours were required to construct the road to the end of segment h-i, then 17.8 hours (120.0-102.2) or 909 feet of segment i-j can be constructed. The road should be constructed 2,159 feet beyond landing C. Landing D would be located 6,034 feet from the harvest boundary; whereas it was originally located 6,775 feet. The skidding patterns would stay the same for landings A and B, and probably C. However, the skidding patterns would change for landing D. If another computer analysis were made in order to obtain a better estimate, then meth-

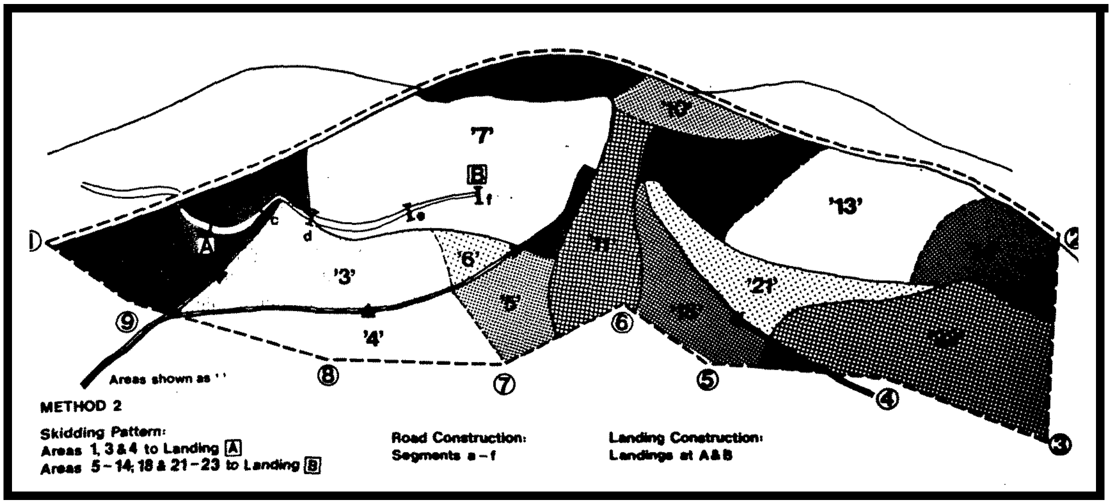

Figure 11.--*Road, landing, and area locations used in method 2.*

Linear programming equations for the harvesting example problem:

Maximize Z:

$$\$95.00\,Q_0 - \$21.63\,H_1 - \$72.26\,H_2 - \$41.35\,H_3 - \$40.00\,H_4 \qquad (7)$$

$$
\begin{array}{rrrrrrrrrll}
1.00\,Q_0 & -567.60\,\lambda_1 & -567.50\,\lambda_2 & -567.50\,\lambda_3 & -567.50\,\lambda_4 & & & & & \leq 0.00 & (8)\\
 & 7.86\,\lambda_1 & 49.07\,\lambda_2 & 75.12\,\lambda_3 & 134.55\,\lambda_4 & -1.00\,H_1 & & & & \leq 0.00 & (9)\\
 & 0.78\,\lambda_1 & 2.64\,\lambda_2 & 4.31\,\lambda_3 & 6.29\,\lambda_4 & & -1.00\,H_2 & & & \leq 0.00 & (10)\\
 & 696.75\,\lambda_1 & 437.15\,\lambda_2 & 374.16\,\lambda_3 & 264.83\,\lambda_4 & & & -1.00\,H_3 & & \leq 0.00 & (11)\\
 & 429.56\,\lambda_1 & 447.83\,\lambda_2 & 455.68\,\lambda_3 & 469.37\,\lambda_4 & & & & -1.00\,H_4 & \leq 0.00 & (12)\\
1.00\,Q_0 & 0.00\,\lambda_1 & 0.00\,\lambda_2 & 0.00\,\lambda_3 & 0.00\,\lambda_4 & & & & & \leq 667.50 & (13)\ \text{(volume)}\\
 & 1.00\,\lambda_1 & 1.00\,\lambda_2 & 1.00\,\lambda_3 & 1.00\,\lambda_4 & & & & & \leq 1.00 & (14)\ \text{(methods)}\\
 & & & & & 1.00\,H_1 & & & & \leq 120.00 & (15)\ \text{(road construction)}\\
 & & & & & & & 1.00\,H_3 & & \leq 600.00 & (16)\ \text{(skidding)}
\end{array}
$$

where: $Q_0, \lambda_m, H_i \geq 0$

ods 1 and 2 should be eliminated. Two new methods should be selected between the original methods 3 and 4. The original method 3 would become the new method 1. By keeping two of the original methods, the amount of new input data needed is reduced and the search area can be systematically analyzed.

Harvesting costs for the optimum method were $59.41 per thousand board feet (¼" Int.). If the constraint on road construction (120 hours) were not binding, then all of method 4 could have been used and harvesting costs would have been $58.31 per thousand board feet. Binding constraints always cause an increase in costs. However, the optimum method selected by the linear program (24% of method 3 and '76% of method 4) is still better than the method 1 ($81.37), method 2 ($65.62), or method 3 ($62.79).

The sensivity analysis in L-O-S-T consists of penalty costs, shadow prices, and ranges on all the cost coefficients and constraints. The formulation used in L-O-S-T and the original input format of the linear program algorithm make it difficult to correlate the variable codes in the sensivity analysis with the correct harvesting costs and constraints. However, users familiar with sensivity analysis should be able to interpret these results in L-O-S-T. In this formulation shadow prices are always zero because all the timber can be harvested by the number of hours computed for each method. The hourly costs of the harvesting functions are always non-basic. In this example, the hourly cost of road construction can increase from $21.63 to $64.43 without changing the optimum solution. This implies that the same road could have been constructed to a higher standard or that more roads should be constructed. The method summary costs also indicated that more roads and landings should be constructed.

LIMITATIONS

The linear programming solution calculated in L-O-S-T is not a global optimum or the absolute best of all possible harvesting methods. The program determines the "best" method based on the methods supplied by the user. Equipment interactions resulting in production delays are not calculated by the program. The effects of equipment interactions must be supplied indirectly by the user through equipment efficiency and area difficulty factors. Harvesting costs are calculated only for road construction, landing construction, system move between landings, skidding, and trucking. While this does not limit the optimization process, an estimate of total harvesting costs is not provided.

EXECUTING L-O-S-T

L-O-S-T is written in FORTRAN IV and is being run under WATFIV on an IBM 3031 at Auburn University. With a modest amount of additional effort, the program could be converted for use on similar computer systems. The example problem described in this report required 264K of storage, used 3.38 seconds of CPU time, and cost about one dollar to run. The FORTRAN source statements used in L-O-S-T are shown in appendix 8. A punched and interpreted source deck (1,914 cards) can be obtained from: Engineering Research Unit, G. W. Andrews Forestry Sciences Laboratory, U. S. Forest Service, Devall Street, Auburn University, Alabama 36849. Phone (205) 887-7542, (FTS) 534-4518.

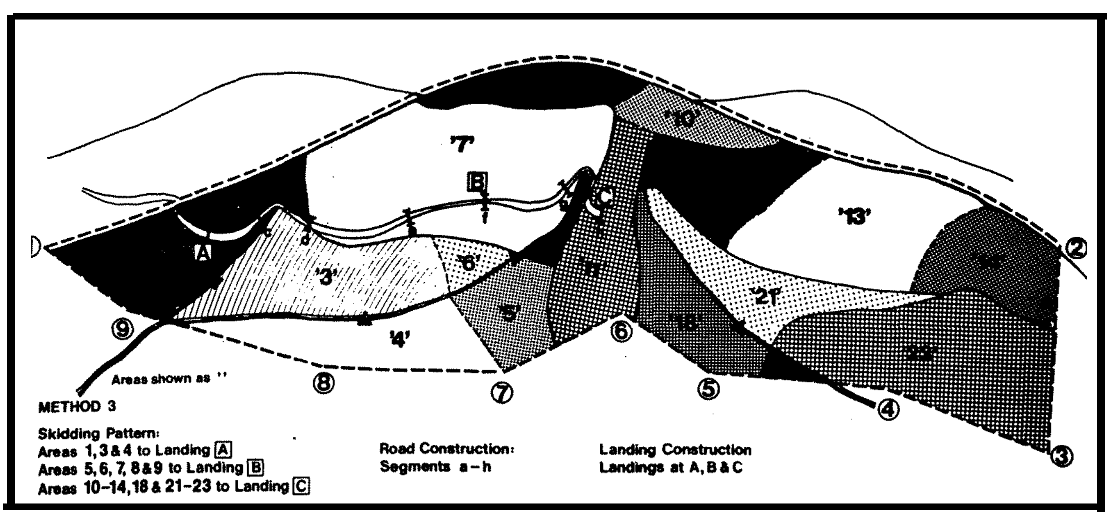

Figure 12.—*Road, landing, and area locations used in method 3.*

RESULTS AND DISCUSSION

A two-part methodology has been developed to analyze user selected harvesting methods. The first part of this methodology considers very specific and realistic harvesting conditions: terrain features, boundary shapes, roads, landings, skidding patterns, and environmental restrictions. Harvesting times and costs are computed for road construction, landing construction, system move between landings, skidding, and trucking. The second part of the methodology uses these harvesting times in a linear programming formulation. The formulation utilizes the relationships among the harvesting methods to estimate and select the harvesting procedure having maximum profits.

Since the analysis performed by L-O-S-T depends on the harvesting methods selected by the users, it is important that users have some knowledge and experience in developing harvesting plans. Time and effort spent in selecting realistic harvesting plans will enable the output from L-O-S-T to be used with greater confidence by managers of harvesting operations.

L-O-S-T does not provide a global optimum with each computer analysis. Theoretically, the procedures used would, through repeated computer runs, find the ultimate harvesting method having maximum profits. L-O-S-T does provide a local optimum and a wealth of information for selecting a better harvesting method. Searching for the elusive global optimum has some academic merit; however, selecting feasible harvesting plans and then systematically quantifying, analyzing, and improving them has greater practical applications.

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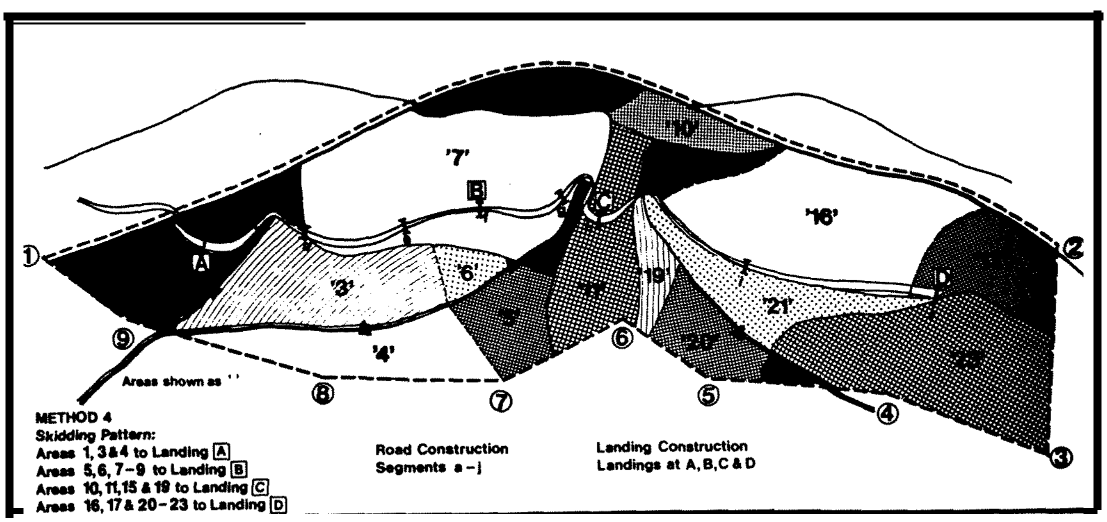

Figure 13.—*Road, landing, and area locations used in method 4.*

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Appendix l-Harvesting Equations, Data, and **Cost Relationships**

HARVESTING EQUATIONS AND DATA

<u>road construction equation</u>: (Koger, equation 3, pg 30, 1978)

$$T = \frac{\frac{X1}{X6}\left[0.524\left[X2/(X3X4)\right]^{0.5} + 12.668\left[X5/(X3X4)\right]^{0.5}\right]}{X7} \quad (A1)$$

where : T = predicted road constructed time in hours
X1 = road length in feet
X2 = number of bank cubic yards per 1,000 feet of road length
X3 = slope correction factor estimated by:

$$1.000 - (\%\ \text{road slope}/100) - 0.0001952\ (\%\ \text{road slope}/100)^2$$

note: % road slope (+, -) is in direction of road construction

X4 = net horsepower of crawler tractor (Table 12, Appendix 4)
X5 = number of acres of cleared road width per 1,000 feet of road length
X6 = road construction difficulty factor with suggested values of:

- 10 for high volume truck road or low volume road constructed adverse conditions
- 500 for low volume truck road constructed under average conditions
- 1,000 for low volume skid road constructed under average conditions
- 2,000 for upgrading existing low volume skid road under average conditions
- 3,000 for low volume landing constructed under average conditions

note: intermediate values (ie. 520, 750) can be used

X7 = (equipment availability)(equipment utilization), with suggested values of:

- 0.50 for low availability and utilization
- 0.85 for average availability and utilization
- 0.95 for high availability and utilization

note: only the variables X1, X4, X6, and Xi' are required as user supplied inputs. The variables X2, X3, and X5 are calculated by the program.

rubber-tired skidder equation (Koger, equation 2, pg 31, 1976)

$$T = (\text{travel empty} + \text{travel loaded} + \text{fixed cycle time})/\text{efficency} \qquad (A2)$$

$$T = \left[\frac{0.0584037\, A^{a} B^{b} C^{c} (1+D)^{d} E^{e} (1+\sin(F))^{f} G^{g}}{H^{h} I^{i}} + \frac{0.00005166\, J^{j} A^{k} B^{l} (1+D)^{m} E^{n} [1+\sin(-F)]^{o} G^{p}}{H^{q} C^{r} I^{s}} + K \right] \frac{1}{L} \qquad (A3)$$

-where : T = cycle time in minutes
- A = one-way skidding distance in feet
- B = radius of curvature in feet (used average study value of 483.99)
- C = net skidder horsepower (Table 13, Appendix 4)
- D = rut depth in inches (used average study value of 6.26)
- E = harvest elevation in feet (used average study value of 1,547.13)
- F = trail slope in degrees(measured in travel loaded direction)
- G = empty skidder weight in pounds (use constant of 20,400)
- H= cone index of soil (used average study value of 192.23
- I = arc length in feet (used average study value of 131.59)
- J = board feet per cycle (1/4 " Int.)
- K = fixed time per cycle in minutes for hooking, decking, etc.
- L = (equipment availability)(equipment utilization), or equipment efficiency

exponents a through s:
a=1.022449; b=3.549048; c=1.317563; d=0.223969; e=0.180727
f=2.156775; g=0.177384; h=0.183381; i=6.943695; j=0.110305
k=1.098034; l=3.472234; m=0.116935; n=0.098604; o=0.681159
p=3.234567; q=0.067053; r=3.157504; s=7.456998

note: Variables B, D, E, G, H, and I remain constant in the program and do not have to be supplied as inputs by the user.

Table 1.--Observed skidding volumes by horsepower*

Horsepower	VOLUME PER CYCLE WHEN MEASURED AS: Pounds			Board Feet: ¼" Int.			Cubic Feet			Cords		
	Low	High	Mean	Low	High	Mean	Low	High	Mean	Low	High	Mean
70	2,205	7,080	5,266	87	617	410	29	117	83	0.38	1.21	0.90
80	3,141	7,129	5,278	233	741	471	43	120	81	0.54	1.21	0.90
92	4,032	6,921	4,987	350	666	464	67	108	82	0.69	1.18	0.85
94	815	19,188	8,124	23	2,403	861	14	294	119	0.14	3.28	1.39
112	2,983	25,450	8,416	141	2,260	715	51	361	128	0.50	4.35	1.44
120	5,005	20,226	12,822	503	2,142	1,334	al	310	199	0.86	3.46	2.19
147**	4,120	7,095	5,468	419	776	575	71	122	94	0.70	1.21	0.93
165**	4,808	5,503	5,155	445	522	484	83	95	89	0.82	0.94	0.88

• (Koger, Table 6, pg 22, 1976)

** Did not observe when stand conditions permitted high volume skidding.

trucking equation

The following equation is used to calculate truck cycle time from landings to the delivery point (mill).

$$Y_{ij} = \frac{O}{S_j} + \frac{O}{F_j} + \frac{X_i}{(E_j(1+C_i))/2} + \frac{X_i}{(L_j(1+C_i))/2} + K_j \qquad (A4)$$

where: Y_{ij} = round trip truck time in hours from the i th landing for the j th truck

O = one-way distance in miles over roads outside the harvest boundary

S_j = average empty travel speed in miles per hour for the j th truck over sections outside the harvest boundary (woods to mill)

F_j = average loaded travel speed in miles per hour for the j th truck over sections outside the harvest boundary (woods to mill)

X_i = distance in miles from beginning of harvest boundary to the i th landing

E_j = empty travel speed in miles per hour over the woods road for the j th truck

C_i = ratio of ending travel speed to beginning travel speed as measured from beginning of harvest boundary to the i th landing

L_j = loaded travel speed in miles per hour over the woods road for the j th truck

K_j = fixed time per cycle in hours for the j th truck

trucking data

Table 2.-- Average truck speed versus road type*

Type of Road	Average Empty Speed (mph)	Average Loaded Speed (mph)
woods	8.34	5.35
Gravel	16.23	13.89
Two-lane black top	38.76	33.78
Interstate	55.00	45.82
city	23.97	21.44

*(Koger, Table 1, pg 5, 1981)

Table 3.--Load characteristic for trucks hauling logs (or tree-length stems)*

Truck Description	Average Number of logs	Average Length (feet)	Average Volume (Doyle)	Average Volume (1/4" Int.)
Single-Axle (1.5-ton)	18	13.6	1,313	1,752
Tandem-Axle (1 drag)	30	12.9	1,937	2,584
Tandem-Axle (2-ton)	35	13.0	2,018	2,693
Tri-Axle (1 drag)	35	15.2	2,648	3,526
Four-Axle (2-drag)	46	11.7	3,276	4,370
Tractor-Trailer (logs)	43	14.5	3,868	5,160
Tractor-Trailer (stems)	35	36.9	4,222	5,632

* (Koger, Table 2, pg 6, 1981)

Table 4.--Load characteristics for trucks hauling pulpwood (bolts, 21-foot stems, or tree-length stems)*

Truck Description	Type of Load	Average Volume (cords)
Single-Axle (0.75-ton)	Pulpwood bolts (5' 3")	1.5
Single-Axle (l-ton)	Pulpwood bolts	2.1
Single-Axle (1.5 ton)	Pulpwood bolts	4.6
Tandem-Axle (1 drag)	Pulpwood bolts	5.3
Tractor-Trailer	Tree-length	8.7
Tandem-Axle (2-ton)	21-foot stems	9.0
Tri-Axle (1 drag)	21-foot stems	9.3
Tractor-Trailer	Pulpwood bolts	9.8

* (Koger, Table 3, pg 6, 1981)

HARVESTING COST RELATIONSHIPS

Landing Construction and System Move

In the linear programming formulation, landing construction and system move times and costs are considered together. The following equation is used to compute a weighted time for landing construction and system moving.

$$WH = (SL + SM)/(HL + HM) \qquad (A5)$$

Where: WH = weighted number of hours for landing construction and system move
SL = sum of landing construction costs for this method
SM = sum of system move costs for this method
HL = hourly landing construction costs
HM= hourly system move costs

Multiple Equipment

In many cases multiple crawler tractors, skidders, or trucks may be used. For example, two rubber-tired cable skidders may be used on the same boundary to skid trees to the landings. Equation A6 is used to compute total time under these conditions. This equation is used for multiple equipment involved in road construction, skidding, or trucking, but not for landing construction. Only one crawler tractor is allowed to construct landings, although two or more are involved in road construction.

$$T = \frac{1}{\frac{1}{H_1} + \frac{1}{H_2} + \ldots + \frac{1}{H_n}} \quad \text{(A6)}$$

where: T = hours required if all equipment (ie. skidders) worked together
H_1 = hours required if this harvesting activity were done entirely by the first machine
H_2 = hours required if this harvesting activity were done entirely by the second machine
H_n = hours required if this harvesting activity were done entirely by the last machine

Equipment Interactions and Efficiency

Equipment interactions resulting in production delays are not directly considered. However, an equipment efficiency factor which considers utilization is available and can be used to model indirectly the effects of delays caused by equipment interactions. Equipment efficiency can be estimated or calculated by the following equation.

$$E = AU \quad \text{(A7)}$$

where: E = equipment efficiency (decimal value greater than 0)
A= equipment availability (decimal)
U = equipment utilization (decimal)

Labor and Equipment Costs

Harvesting costs computed in L-C-S-T are based on only the harvesting functions considered in the optimization analysis (road construction, landing construction, system move between landings, skidding, and trucking). Hourly labor cost includes the base wage rate plus social security and workmen's compensation. Hourly equipment costs include fixed and operating costs based on a scheduled hour. Miyata (1980) discusses fixed and operating costs for timber harvesting equipment and provides several examples of the different methods available. The following equation reported by Nichols (1962) is a simple rule-of-thumb method that can be used to determine the approximate scheduled hourly cost of timber harvesting equipment used in L-C-S-T.

$$C = 0.0003(P) \tag{A8}$$

where: C = hourly equipment costs (excluding labor)
P = purchase price of equipment or purchase price of an equivalent piece of new equipment

Appendix Z-Determining and Using Skidding Distances

Determining Skidding Distance

In L-O-S-T, a distinction is made between average skidding distance (ASD), average travel distance (ATD), and fixed skidding distance (Figure I). The equations developed by Suddarth (1952) for average skidding distance on simple geometric shapes are shown in Figure II. Greulich (1980) extended this and included the influence of slope on the equations he developed for average skidding distance on areas with simple geometric shapes. For irregular shaped areas, average skidding distance can be accurately computed using a desk-top programmable calculator and digitizer (Peters and Burke 1972).

In most cases there is very little difference between the values obtained for average skidding distance using the mathematical equations derived by Suddarth (1952) and those obtained by determining the straight line distance from the landing to the centroid of the area. For example, if the landing is located at the corner of a mile square area, then the average skidding distance computed by Suddarth's equation is 4,040.23 feet. The straight line distance from the landing to the centroid (2640,2640) of the area is 3,733.52 feet. A simple graphical method for estimating average skidding distance on irregular shaped areas is shown in Figure III.

While average skidding distance has an exact mathematical definition (Suddarth 1952), its use, nevertheless, represents a simplification of the skidding process. If average skidding distance is used, then all the trees on the area are essentially assumed to be located an equal distance (average skidding distance) from the landing. However, trees are scattered over the area and skidding usually starts near the landing and proceeds to the farthest boundary of the harvest area. A more accurate estimate of skidding cycle time can be obtained by integrating the skidding equation (A3) over the range of skidding distances. Similarly, using an average skidding cycle volume rather than the range of cycle volumes causes equation A3 to underestimate skidding times. In L-O-S-T, users have the options of using average values for skidding distance and volume or their ranges. For simplicity reasons, the simplifed version (A10) of the skidding equation will be used to illustrate the integration procedures (All) available in L-O-S-T, given below.

$$Y = \text{travel empty time} + \text{travel loaded time} + \text{fixed time} \tag{A9}$$

$$Y = 0.0027(X)^{1.022} + 0.00088(X)^{1.098}(V)^{0.11} + K \tag{A10}$$

where: Y = cycle time in minutes for articulated, four-wheel drive, rubber-tired skidders in the 70 to 130 horsepower range
X = one-way skidding distance in feet
V = cycle volume in board feet (1/4 Int.); must be reasonable for skidder size and skid trail conditions (Table 1, Appendix 1)
K = assumed fixed time (minutes) per cycle for hooking, decking, etc.

$$Y = \frac{0.0027}{b-a}\int_a^b (X)^{1.022}\,dx + \frac{0.00088}{(b-a)(d-c)}\int_a^b\int_c^d (X)^{1.098}(V)^{0.11}\,dx\,dv + K \tag{A11}$$

where: Y = skidding cycle time in minutes
a = lower limit on skidding distance in feet
b = upper limit on skidding distance in feet
c = lower limit on skidding volume in board feet (1/4" Int.)
d = upper limit on skidding volume in board feet (1/4" Int.)
x = skidding distance, feet
V = skidding volume, board feet (1/4" Int.)
dx = derivative of Y with respect to X
dv = derivative of Y with respect to V
K = fixed time per cycle in minutes for hooking, decking, etc.

Actual Travel Distance

Due to terrain features (steep slopes, streams, rocks, soft ground) and to stand characteristics (large stumps, dead snags), the distance actually traveled by the skidder from the landing to the woods is rarely ever equal to the straight-line value computed for average skidding distance. Koger (1976) found that a correction factor of 1.86 was needed to adjust average skidding distance to the actual travel distance. The user can supply this correction factor (1.86) or one pertinent to area conditions through the input variable, AC (card type 13, Appendix 5). In most cases, if some correction factor is not used, skidding costs will be significantly underestimated.

Fixed Skidding Distance

In most cases an area (Figures 10-13) will not be adjacent to a landing. The distance traveled by the skidder from the landing to reach the area boundary is referred to as the fixed skidding distance. This value must be calculated or estimated by the user and coded in the input data (variabale AF, card type 13, Appendix 5).

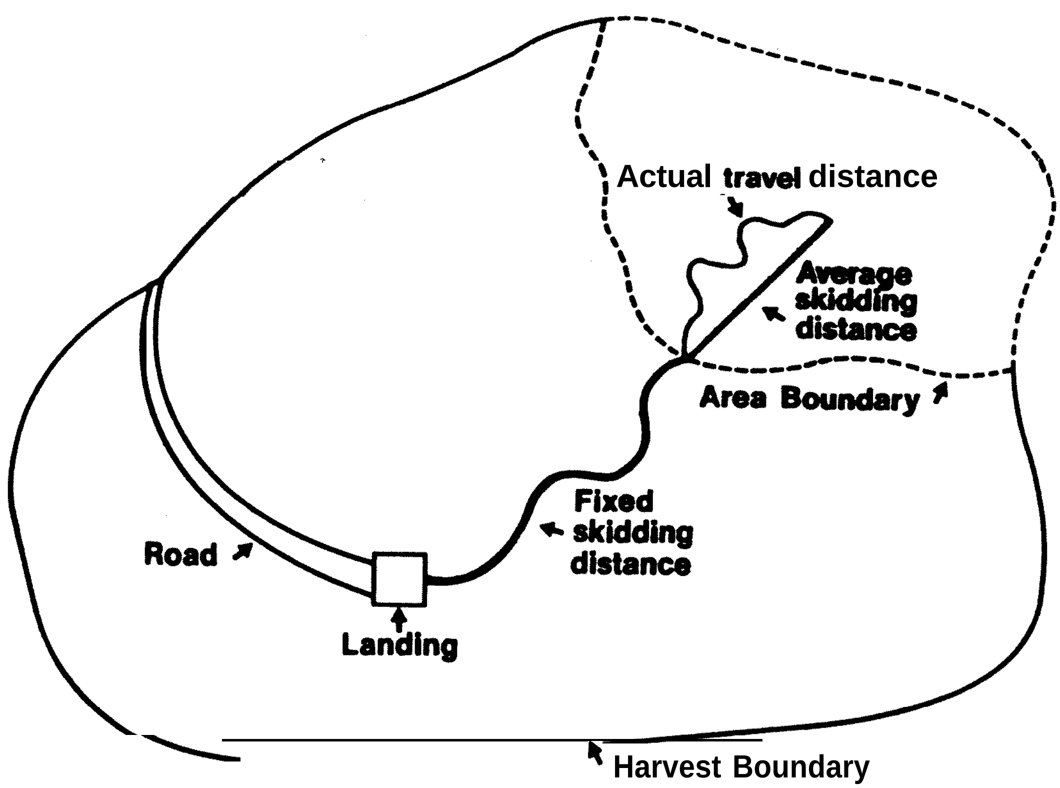
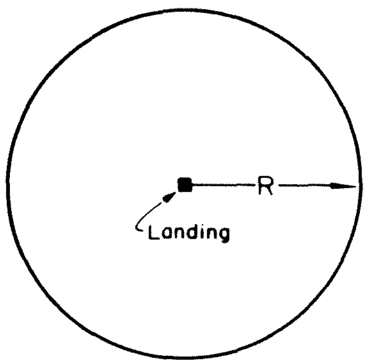


Figure I.--Relationship among average skidding distance, actual travel distance, and fixed skidding distance

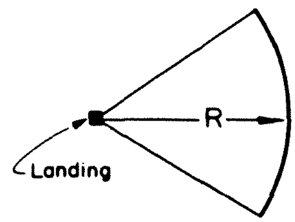
AVERAGE SKIDDING DISTANCE (ASD) FOR SIMPLE GEOMETRIC SHAPES

CIRCLE (Suddarth 1952)



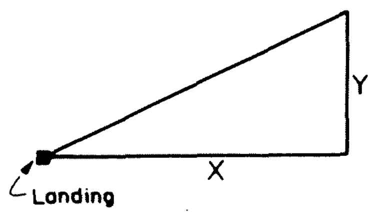
$$ASD = (2/3)R$$

CIRCULAR SEGMENT (Suddarth 1952)



$$ASD = (2/3)R$$

RIGHT TRIANGLE (Suddarth 1952)



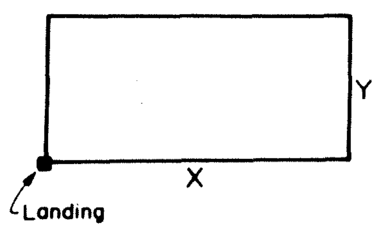
$$ASD = \sqrt{\frac{x^2+y^2}{3}} - \left[\frac{x^2}{3y}\right] \ln \left[\tan\left\{\frac{\arctan\left(\frac{x}{y}\right)}{2}\right\}\right]$$

ANY TRIANGLE (Peters 1978)

L a n d i n g -

$$ASD = \frac{r_1+r_2}{6r_3^2}\left[r_3^2+(r_1-r_2)^2\right] + \frac{\left[r_3^2-(r_1-r_2)^2\right]\left[(r_1+r_2)^2-r_3^2\right]}{12r_3^3} \ln\left[\frac{r_1+r_2+r_3}{r_1+r_2-r_3}\right]$$

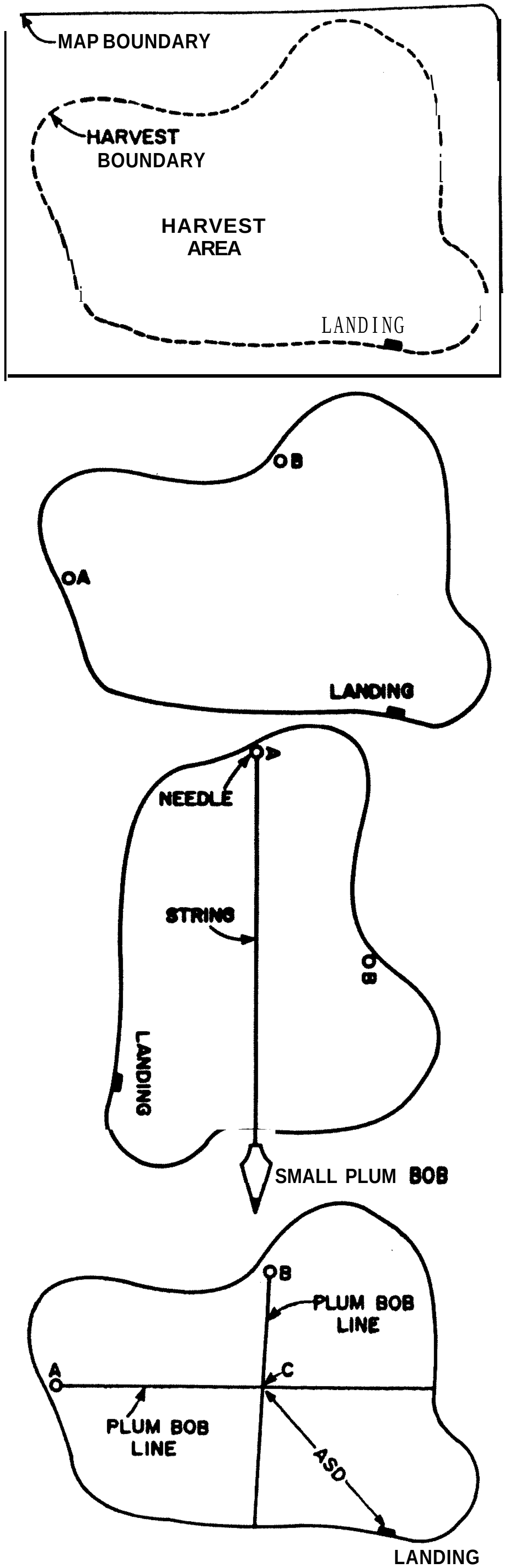
RECTANGLE (Suddarth 1952)



$$ASD = \sqrt{\frac{x^2+y^2}{3}} - \left(\left[\frac{y^2}{6x}\right] \ln\left[\tan\left\{\frac{\arctan\left(\frac{y}{x}\right)}{2}\right\}\right]\right) - \left(\left[\frac{x^2}{6y}\right] \ln\left[\tan\left\{\frac{\arctan\left(\frac{x}{y}\right)}{2}\right\}\right]\right)$$

Where ln = natural log. base e : tan = tangent : arctan = arctangent

Figure II. --Average skidding distance equations for areas with simple geometric shapes



STEP 1: DETERMINE HARVEST BOUNDARY AND LANDING LOCATION.

STEP 2: SEPARATE HARVEST AREA FROM MAP BY CUTTING ALONG HARVEST BOUNDARY LINE.

STEP 3: MAKE TWO SMALL HOLES NEAR MARGIN OF HARVEST BOUNDARY (A & B). SEPARATE FROM LANDING BY ABOUT 1/3 BOUNDARY CIRCUMFERENCE.

STEP4: PLACE A NEEDLE IN HOLE AT LOCATION (A) AND MAKE SURE THAT HARVEST AREA CUTOUT ROTATES FREELY ABOUT THE NEEDLE AXIS. ATTACH A SMALL PLUM BOB TO NEEDLE AND MARK PLUM LINE ON CUTOUT. REPEAT THIS PROCESS AT LOCATION (B).

STEP 5: THE CENTROID OF THE HARVEST AREA WILL BE AT THE INTERSECTION OF THE TWO PLUM BOB LINES (C). MEASURE THE DISTANCE FROM POINT C TO THE LANDING WITH A RULER. THIS DISTANCE MULTIPLIED BY THE MAP SCALE WILL GIVE A CLOSE APPROXIMATION OF AVERAGE SKIDDING DISTANCE(ASD).

Figure III.--Graphic method for determining average skidding distance when landing is on boundary edge

Appendix 3-Harvesting Example Problem Method Assumptions

Table 5 .--Harvesting equipment assumptions

Equipment Description	Equipment Efficiency Factor	Cycle Volume (1/4" Int. Bdft)	Scheduled Hourly costs ($) +
crawler tractor (72 hp)*	0.70	NA	$21.63
rubber-tired skidder (70 hp)*	0.80	400 - 510	19.05
rubber-tired skidder (90 hp)*	0.85	420 - 550	22.30
tandem-axle truck (2 ton)	0.80	1,800	19.50
tandem-axle truck (2 ton)	0.80	2,000	20.50
knuckleboom loader*	NA	NA	13.00
repair truck*	NA	NA	8.50

+ includes $5.50 per scheduled hour for labor costs
* equipment involved in system move between landings

Table 6.--Road segment data

Road Section	Road Length 350 (feet)	Road Width 15 (feet)	Constructed Slope (%)	Sidehill Slope (%)	Cut Ratio (feet)	Fill Ratio (feet)	Building Difficulty
a - b	450	15	-10	10	1.5	1.5	100
b - c			-8	15	1.5	1.5	150
c - d	325	15	-10	12	1.5	1.5	100
d - e	800	15	-10	12	1.5	1.5	150
e - f	600	14	-8	10	1.5	1.5	100
g - g	700	14	-10	8	1.5	1.5	150
h - h	650	12 13	-15 -12	20 15	1.5	1.5	100 100
i - j	1,250 1,650	12	-6	10	1.5	1.5	100

Table 7 .--Landing construction data

Method Number	Landing Code Letter	Distance From Harvest Boundary (feet)	Landing Size (acres)	Average Depth of cut (feet)	Construction Difficulty Factor	Equipment System Move Time (hours)
1	A	350	1.5	0.3	1.00	0.0
2	A	350	0.6	0.3	1.00	0.0
2	B	2,525	1.5	0.4	0.90	2.0
3	A	350	0.6		1.00	0.0
3	B	2,525	0.8	0.3		
3	C		1.5	0.4	0.90 1.00	2.0 1.8
4	A	3,875 350	0.6	0.3	1.00	0.0
4	B	2,525	0.8	0.4	0.90	2.0
4	C	3,875	0.9	0.4	1.00	1.8
4	D	6,775	1.2	0.3	0.80	2.2

Table 8.--Skidding data for method 1

Landing Code	Area Code	Area Volume (1/4"Int)	Area Size (acres)	Average Skidding Distance (feet)	Fixed Skidding Distance (feet)	Trail Slope (%)	Fixed Cycle Time (min)
A	1	65,000	26	485	0	-2	7
A	2	70,000	28	1,005	265	-3	7
A		40,000	16	525	2,080		
A		22,500		415	3,700	-5	3
	5		9				9
A	7	94,000	45	1,275	4,200	-10	9
A	9	15,000	10	840	3,000	-10	11
A	10	12,000	8	285	4,950	-2	11
A	11	24,000	16	1,095	4,550	5	11
	13						13
A	14	27,000	21	990	6,230	10	13
A		15,000	15	570	8,000	5	13
A	18	26,000	13	520	5,740	15	9
A	21	30,000	15	1,095	5,050	12	9
A	22	6,000	2	170	7,700	10	5
A	23	105,000	35	900	7,225	10	5

Table 9.--Skidding data for method 2

Landing Code	Area Code	Area Volume (1/4"Int)	Area Size (acres)	Average Skidding Distance (feet)	Fixed Skidding Distance (feet>	Trail Slope (%)	Fixed Cycle Time (min)
				485			
A	1	65 000	26	820 40	0	5	7
	3	,000				5	7
A	5	57,500	23	525	2,990	-3	7
B	6	22,500	9	415	600	10	7
B		12,500		190		12	7
			5				9
B	8	94,000	45	275	1,300	-8	9
B	10 9	15,000	10 8	445	990	-10 -10	11 11
		12,000			1,680		
B	11	24,000	16	1,095	1,290	-2	11
B		16,000	16	625	1,780	5	13
	12						13
B	14	27,000	15	990	2,670	10	13
B	21	26,000	13	520	2,080	5	9
B	22	30,000	15	1,095	1,880	15	9
		6,000	2				5
B	23	105,000	35	900	3,660	10	5

Table 10.--Skidding data for method 3

Landing Code	Area Code	Area Volume (1/4"Int)	Area Size (acres>	Average Skidding Distance (feet)	Fixed Skidding Distance (feet)	Trail Slope (%)	Fixed Cycle Time (min)
							7
A	3	65,000	26	485	0	5	7
A	4	40,000	23	525	2,080	-3	7
	5		9		990		7
B	6	12,500	5	190	600	10	7
	7			275			9
B	8	94,000	45	445	1,300	-8	9
B	9	15,000	10		990	-10	11
C	10	12,000	8	285	0	-10	11
C	11	24,000	16	1,095	300	-2	11
C	12	16,000	16	625		5	13
C	13	27,000	15	990	1,390	10	13
C	14	15,000	13	570	3,660	10	13
						5	9
C	18	30,000	15	1,095	700	15	9
			2				5
C	23	105,000	35	900	2,870	10	5

Table 11.--Skidding data for method 4

Landing Code	Area Code	Area Volume (1/4"Int)	Area Size (acres)	Average Skidding Distance (feet)	Fixed Skidding Distance (feet)	Trail Slope (%)	Fixed Cycle Time (min)
A	1	65 000	26	405	0	5	7
A			23	525	265	5	7
A	2	57,500	16	415	2,080	-3	7
B	5	22,500	9		990	10	7
B	6	12,500	5	190	600	12	7
	7					-2	9
B	8	94,000	45	630	1,300	-8	9
C	9	15,000	10	275	990	-10	11
C	10	24,000 12,000	16 8	1,095 445	790 0	-10 -2	11
	11			285	300	-5	11
C	15	6,000	6	490	790	-5	13
C	19	10,000	5	270			9
D	16	37,000	37	900	500	-4	13
D	17	15,000		450		-5	13
			15		0	3	9
D	20	16,000	18	1,170	2,370	4	9
			2			4	5
D	23	105,000	35	120	2,850	6	5

Appendix 4-Equipment Specifications

Table 12.-Equipment horsepower and weight characteristics
for selected crawler tractors

Equipment Make & Model		Equipment Horsepower (net engine)	Equipment Weight (bare, pounds)
Case	350	39	5,905
	450	51	8,850 05
	850	72	13:00o
	1450	130	23,800
Caterpillar	D3-PS	62	10,300
	D4-DD	75	13,990
	D5-DD	105	19,200
	D6-DD	140	24,000
John Deere	JD350-C	42	8,160
	JD450-C	65	11,600
	JD550	72	12,300
International	TD-7E-PS	65	10,459
	TD-8E-PS	78	13,834
	TD-15C-PS	140	24,153
Komatsu	D45A-1	90	18,340
	D53A-15		
	D60A-6	110 140	22,200 28,220
Massey-Ferguson	MF300	65	14,700
	MF400	85	20,585
	MF5WB	136	25,800

Table 13.--Equipment horsepower and weight characteristics for selected rubber-tired skidders

Equipment Make & Model	Equipment Horsepower (net engine)	Equipment Weight (bare, pounds)
Athey S-97D	97	16,250
Caterpillar 518	120	20,400
528	175	28,300
Clark Ranger 664B	82	15,890
666B	112	17,855
.668B	166	24,480
	70	
Franklin 531	80	12,000
132		17,840
170	112	18,740
185	775	24,140
International S8	86	13,100
John Deere JD440-B	70	12,250
JD540-A	94	16,150
JD640	110	19,900
JD740	145	26,700
Pettibone 100	93	14,950
Timber Jack 208D	67	12,300
225	92	12,784
Tree Farmer C5D	90	15,890
C6D	120	18,180

Appendix 5—Data Card Types

The following 17 data card types are used in L-O-S-T to describe organized input data for the harvesting methods, areas, road segments, landings, and equipment. Unless otherwise stated, all input data is to be right justified. Input variable names beginning with INTEGER letters (I,J,K,L,M, *or* N) do not require decimal points. Input variable names beginning with REAL letters (A-H, & O-Z) do require a decimal point in the input field location shown. Although harvest volume units of pounds, 1/4" Int. board feet, cubic feet, or cords may be used, once a unit has been selected it must be used throughout the analysis. The input data for the harvesting example shown in Appendix 6 should be used to supplement the data card type descriptions given below.

Card Type 1: (required; one card)

Columns	Variable	Description
1 ... 64 cc	ATITLE()	harvesting problem title

Card Type 2: (required; one card)

Columns	Variable	Description
2 cc	NMETH	number of methods analyzed (minimum of 2 and a maximum of 4)
5 cc	NDZR	number of crawler tractors (1-5)
7 8 cc	NSKD	number of rubber-tired, cable skidders (1-10)
10 11 cc	NTRK	*number* of trucks (1-10)
13 cc	ICTRAT	number of user supplied constraints (O-4); allows limits on number of hours permitted for harvesting functions considered
15 cc?	ILPANA	linear programming option code: = 0 if linear programming analysis is performed = 1 if linear programming analysis is not performed
17 cc	LPCDE	= 0 if no intermediate matrices are printed; the normal case = 1 if intermediate matrices are printed; is helpful in understanding sensivity analysis

Card Type 3: **(required;** one card)

Card columns	Variable	Description
1 cc /_/	**IUNIT**	unit code for volume; = 1 for pounds = 2 for 1/4" Int. board feet = 3 for cubic feet = 4 for cords
3 12 cc /_/_/_/_/_/_/_/_/_/_/	HARVOL	total volume of harvested timber in same units as coded for **IUNIT**
14 18 20 cc /_/_/_/_/_._/_/	PRODPC	selling or delivered price in normal selling units **(ie.** $/1,000 board feet)
22 26 28 cc /_/_/_/_/._/_/	**SYSMHC**	hourly cost **($/hr)** to move pertinent equipment to the next landing; not an hourly move-in cost
30 35 cc /_/_/_/._/_/	DFTBTM	distance in miles from mill **to harvest** boundary or start of constructed woods' roads (can be zero if analyzing trucking within harvest boundary)

Card Type 4: (required; one card for each crawler tractor building roads ; **NDZR** cards required; cards adjacent)

Card columns	Variable	Description
1 4 cc /_/_/_/._/	**DZRHP()**	net horsepower of crawler tractor; (Table 12, Appendix 4)
6 9 cc /_/._/_/_/	**DZREF()**	crawler tractor efficiency **(ie. 0.80)**
11 14 16 cc /_/_/_/._/_/_/	**DZRHC()**	hourly crawler tractor and operator cost **($/hr)**

Card Type 5: (required; one card for each skidder; NSKD cards required; cards adjacent)

Card columns	Variable	Description
1 4 cc /_/_/_/._/	**SKDHP()**	net skidder horsepower; (Table 13, Appendix 4)
6 11 cc /_/_/_/_/_/._/	**SKDWT()**	weight of unloaded skidder in pounds; (Table 13, Appendix 4)
13 16 cc /_/._/_/_/	**SKDEF()**	skidder efficiency **(ie.** 0.75)

18 21 23 cc
/_/_/_/./_/_/ SKDHC() hourly skidder and operator cost ($/hr)

Card Type 6: (required; one card for each truck; NTRK cards required; cards adjacent); note: travel speeds must be > 0.

Columns	Variable	Description
1 4 cc /_/_/./_/	TKTENW()	empty truck travel speed in mph over non-woods road (Table 2, Appendix 1)
6 9 cc /_/_/./_/	TKTLNW()	loaded truck travel speed in mph over non-woods road (Table 2, Appendix 1)
11 14 cc /_/_/./_/	TKTEWD()	empty truck travel speed in mph over woods road (Table 2, Appendix 1)
16 19 cc /_/_/./_/	TKTLWD()	loaded truck travel speed in mph over woods road (Table 2, Appendix 1)
21 24 cc /_/_/./_/	TKFTPC()	fixed time per cycle in minutes; can include delays, stops for fuel, etc.
26 29 cc /_/./_/_/	TKEF()	truck efficiency (ie. 0.80)
31 38 40 cc /_/_/_/_/_/_/_/_/./_/_/	TKVOL()	average truck volume (Tables 3 & 4, Appendix 1); same units as IUNIT in card type 3
42 45 47 cc /_/_/_/_/./_/_/	TKHC()	hourly truck and operator cost ($/hr)

Card Type 7: (required; one card for each method; NMETH cards required; cards adjacent)

Columns	Variable	Description
1 cc /_/	IMETH()	method number (1-4)
4 cc /_/_/	IRDSEG()	number of road segments for this method (0-20)
7 cc /_/	ILANDN()	number of landings for this method (1-8)

Card Type 8: (required; one card for each landing for each method; cards adjacent)

Columns	Variable	Description
1 cc /_/	JMN	method number--not number of methods (1-4)

4 cc
/_/ JLN — landing number--not number of landings (1-8)

7 cc
/_/_/ JNA — number of areas for this landing (1-25); not area code number

10 cc
/_/_/ JMAN — maximum value of any area code number for this landing; is equal to JNA only if areas are numbered consecutively

Card Type 9: (required; one card)

1 cc
/_/ JMN — control card which follows the last card type 8 and must have a 0 (zero) coded in card column 1

Card Type 10: (required; one card for each road segment for each method; cards adjacent)

1 7 cc
/_/_/_/_/_/_1.1 ROADSL — length of road segment in feet; if there are no road segments code a 0 (zero) in card column 6 and then skip other variables on this card type

9 12 cc
/_/_1.1_/ ROADSW — segment road width in feet

14 18 cc
/_/_/_/_1.1 ROADSP — percent slope (+,-) or road segment in direction of construction

20 24 cc
/_/_/_/_1.1 ROADSS — percent slope (+ only) of side-hill adjacent road

26 28 30 cc
/_/_/a/_/_/ ROADCR — cut ratio; rise in cut per 1 foot of base (ie. 1.50)

32 34 36 cc
/_/_/./_/_/ ROADFR — fill ratio; drop in fill per 1 foot of base (ie. 1.50)

38 42 cc
/_/_/_/_/./ ROADTY — road construction difficulty code;
= 10 for road constructed under adverse conditions or for high volume truck traffic
= 500 for road constructed under average conditions
= 1000 for road constructed under favorable conditions

= 2000 for road constructed under very favorable conditions, or the up-grading of an existing road
= 3000 for landing constructed under average conditions

note: intermediate values (ie. 520, 760) can be used; trial and error techniques may be required to obtain desired or expected times and costs

Card Type 11: (required; one card)

1 cc /_/	ILDZR	input order number of crawler tractor in card type 4 that will be used to construct all landings (ie. if the second crawler tractor in card type 4 is used, then code a 2 in card column 1); only one crawler tractor is permitted to construct landings

Card Type 12: (required; one card for each landing for each method; cards adjacent; input all landings for first method, then all landings for second method, etc.)

1 8 cc /_/_/_/_/_/_/_/_/./	DSFTB()	distance in feet this landing is from harvest boundary as measured along woods road
10 13 cc /_/_/./_/	ACRESL	landing size in acres
15 18 cc /_/_/./_/	CUTL	average depth in feet of earth removed in constructing this landing
20 23 cc /_/./_/_/	EFFL	landing construction difficulty factor; must be greater than 0.0; suggest: = less than 1.00 for difficult sites = 1 .0 for average sites = greater than 1 .0 for favorable sites
25 29 cc /_/_/_/./_/	SYSMHR	number of hours required to move equipment to this landing; not a move-in time, but a system move between landing time; should be 0 (zero) for the first landing

Card Type 13: (required; one card for each area for each method; cards adjacent)

1 cc /_/	IMN	method number

Card columns	Variable	Description
3 cc /_/	ILN	landing number
5 cc /_/_/	IAN	area code number
6 14 cc /_/_/_/_/_/_/_/_/./	AV	area volume in same units used for variable IUNIT in card type 3
15 20 cc /_/_/_/_/_/./	AA	area acres
21 28 cc /_/_/_/_/_/_/_/./	AN	average or minimum skidding distance in feet for this area; if AN=AX (next variable) average skidding distance option is assumed and skidding time is not based on integration (dx)
29 36 cc /,/,/_/_/_/_/_/./	AX	average or maximum skidding distance in feet for this area; if AX=AN (last variable) average skidding distance option is assumed and skidding time is not based on integration (dx)
37 44 cc /_/_/_/_/_/_/_/./	AF	fixed skidding distance in feet from landing to start of harvest area; is 0 (zero>. if landing is located on edge or inside of harvest area; this is actual travel distance and not straight line distance (Figure I, Appendix 2)
46 48 50 cc /_/_/./_/_/	AC	correction factor adjusting straight line skidding distance to actual distance traveled by skidder inside an area; suggest 1.86; use 1.00 for no correction
52 56 cc /_/_/_/_/./	AS	slope of skid trail (+,-) in percent, measured in travel loaded direction
58 61 cc /_/./_/_/	AD	difficulty factor code used to provide more sensitivity for actual skidding conditions on each area; can be used to model increased skidder interactions, multiple skidders on small areas, or adverse skidding conditions; = less than 1 .OO for adverse skidding conditions or high skidder interaction = 1.00 for average skidding conditions and no significant skidder interaction = greater than 1 .OO for very favorable skidding conditions and no skidder interactions

63 66 cc /_/_/./_/	AT	average fixed skidding time per cycle in minutes (ie. hooking, unhooking, decking)

Card Type 14: (required; one card)

1 cc /_/	IMN	control card which follows the last card type 13; must have a 0 (zero) coded in card column 1

Card Type 15: (required; one card for each method, for each landing, for each area, for each skidder; cards adjacent)

1 cc /_/	KM	method number (1-4)
4 cc /_/	KL	landing number (1-8)
7 cc /_/_/	KA	area code number; same as IAN in card type 13
10 cc /_/_/	KS	skidder input order number; must be in same sequence as coded in card type 5.
11 20 cc /_/_/_/_/_/_/_/_/_/./_/	SKVMN	average or minimum volume skidded per cycle; if SKVMN=SKVMX (next variable) average skid volume is assumed and skidding time is not based on integration (dv); volume ranges (Table 1, Appendix 1); volume must be in same units as used for variable IUNIT in card type 3
21 30 cc /_/_/_/_/_/_/_/_/_/./_/	SKVMX	average or maximum volume skidded per cycle; if SKVMX=SKVMN (last variable) average skid volume is assumed and skidding time is not based on integration (dv); volume ranges (Table 1, Appendix 1); volume must be in same units as used for variable IUNIT in card type 3

Card Type 16: (required; one card for each landing for each method; cards adjacent)

1 cc /_/	ITMN	method number (1-4)
4 cc /_/	ITLN	landing number (1-8)

6 9 cc
/_/./_/_/ TKTVCF truck speed correction fac tor ; ref lee ts change in truck travel speed as a function of distance traveled over woods road; ratio of ending travel speed on woods road to beginning travel speed on woods road; a value of 1.00 would indicate the use of average travel speed

Card Type 17: (optional; use only if adding constraints for number of hours; use only if value of ICTRAT in card type 2 is greater than zero; one card required for each constraint; cards adjacent; most often used after one computer analysis has been made without upper bound constraints; upper bound values are usually not know in advance of an initial unconstrained analysis

1 cc
/_/ ICSTFO constraint code:
= 1 if supplying upper bound on road construction hours
= 2 if supplying upper bound on landing construction and system move hours
= 3 if supplying upper bound on skiding hours
= 4 if supplying upper bound on trucking hours

3 10 cc
/_/_/_/_/_/_/_/_/./ upper bound value of constraint in hours

Appendix 6-Harvesting Example Problem Input Data

```
HYPOTHETICAL HARVESTING EXAMPLE: 4 METHODS
 4  12  2201
2    567500.   95.00   50.63  30.5
 72.  0.70  21.63
 70.  14175.  0.80 19.05
 90.  16675.  0.85 22.30
34.0 28.0 8.3 5.3 15.0 0.80    1800.00   19.50
34.0 26.0 8.3 5.0 15.0 0.80    2000.00   20.50
1  1  1
2  5  2
3  7  3
4  9  4
1   11623
2 1 3   4
2   21423
3   13   4
3  2  5  9
3  3   923
4 1 3_  4
4  2  5  9
4  3  4 19
4  4  623
0
   350.  15.0  -10.   10.   1.50  1.50   100.
   350.  15.0  -10.   10.   1.50  1.50   100.
   450.  15.0   -8.   15.   1.50  1.50   150.
   325.  15.0  -10.   12.   1.50  1.50   100.
   800.  15.0  -10.   12.   1.50  1.50   150.
   600.  14.0   -8.   10.   1.50  1.50   100.
   350.  15.0  -10.   10.   1.50  1.50   100.
   450.  15.0   -8.   15.   1.50  1.50   150.
   325.  15.0  -10.   12.   1.50  1.50   100.
   800.  15.0  -10.   12.   1.50  1.50   150.
   600.  14.0   -8.   10.   1.50  1.50   100.
   700.  14.0  -10.    8.  1.50  1.50   150.
   650.  13.0  -15.   20.   1.50  1.50   100.
   350.  15.0  -10.   10.   1.50  1.50   100.
   450.  15.0   -8.   15.   1.50  1.50   150.
   325.  15.0  -10.   12.   1.50  1.50   100.
   800.  15.0  -10.   12.   1.50  1.50   150.
   600.  14.0   -8.   10.   1.50  1.50   100.
   700.  14.0  -10:    8.  1.50  1.50   150.
   650.  13.0  -15.   20.   1.50  1.50   100.
  1250.  12.0  -12.   15.   1.50  1.50   100.
  1650.  12.0   -6.   10.   1.50  1.50   100.
1
    350.   1.5  0.3  1.00  0.0
    350.   0.6  0.3  1.00  0.0
   2525.   1.5  0.4  0.90  2.0
```

350.	0.6	0.3	1.00	0.0
2525.	0.8	0.4	0.90	2.0
3875.	1.5	0.4	1.00	1.8
350.				0.0
2525.	0.6	0.3	1.00	2.0
3875.	0.8	0.4	1.00	1.8
6775.	1.2	0.3	0.80	2.2

1 1 1	65000.	26.	485.	485.	0.	1.9	5.	1.00	7.0
1 1 2	70000.	28.	1005.	1005.	265.	1.9	-2.	1.00	7.0
1 1 4	40000.	16.	525.	525.	2080.	1.9	-3.	1.00	7.0
1 1 5	22500.	9.	415.	415.	3700.	1.9	-5.	1.00	7.0
1 1 '7	90000.	45.	1180.	1180.	1200.	1.4	-10.	1.00	9.0
1 1 8	4000.	2.	275.	275.	4000.	1.4	-8.	0.90	9.0
1 1 9	15000.	10.	840.	840.	3000.	1.4	-10.	1.00	11.0
1 110	12000.	8.	285:	285.	4950.	1.4	-2.	1.00	11.0
1 111	24000.	16.	1095.	1095.	4550.	1.4	+5.	0.95	71.0
1 112	16000.	16.	625.	625.	5050.	1.5	+10.	0.85	13.0
1 113	27000.	27.	990.	990.	6230.	1.5	+10.	0.90	13.0
1 114	15000.	15.	570.	570.	8000.	1.5	+5.	0.90	13.0
1 118	26000.	13.	520.	520.	5740.	1.5	+15.	0.80	9.0
1 121	30000	15.	1095.	1095 .	5050.	1.7	+12.	0.90	9.0
1 122	6000.	2.	170.	170.	7700.	1.7			
1 123	105000:	35.	900.	900.	7225.	1.7	+10.	1.00 1.00	5.0 5.0
2 1 1	65000.	26.	485.	485.	0.	1.6	5.	1.00	7.0
2 1 3	57500.	23.	820.	820.	265.	1.6	5.	1.00	7.0
2 1 4	40000.	16.	525.	525.	2080.	1.6	-3.	1.00	7.0
2 2 5	22500:	9.	415.	415.	990.	1.6	10.	1.00	7.0
2 2 6	12500.	5.	190:	190:	600.	1.6	12.	1.00	7.0
2 2 7	90000.	45.	630.	630.	0.	1.6	-2.	1.00	9.0
2 2 8	4000.	2.	275.	275.	1300.	1.6	-8.	1.00	9.0
2 2 9	15000.	10.	445.	445.	990.	1.6	-10.	1.00	11.0
2 210	12000.	8.	285:	285.	1680.	1.4	-10.	1.00	11.0
2 211	24000.	16.	1095.	1095.	1290.	1.4	-2.	1.00	11.0
2 212	16000.	16.	625.	625.	1780.	1.4	5.	0.95	13.0
2 213	27000.	27.	990.	990.	2670.	1.4	10.	0.85	13.0
2 214	15000.	15.	570.	570.	5050.	1.9	10.	0.90	13.0
2 218	26000.	13.	520.	520.	2080.	1.5	5.	0.90	9.0
2 221	30000.	15.	1095.	1095.	1880.	1.5	15.	0.80	9.0
2 222	6000.	2.	170.	170.	3660.	1.5	12.	1.00	5.0
2 223	105000:	35.	900.	900.	4260.	1.9	10. 5.	1.00 1.00	7.0 5.0
3 1 1	65000.	26.	485.	485.		1.9			
3 1 3	57500.	23.	820.	820.	26;:	1.9	-3. 5.	1.00 1.00	7.0 7.0
3 1 4	40000.	16.	525.	525.	2080.				
3 2 5	22500:	9.	415.	415.	990.	1.6	10.	1.00	7.0
3 2 6	12500.	5.	190.	600.	600.	1.6	12.	1.00	7.0
3 2 7	90000.	45.	630.	630.	0.	1.6	-2.	1.00	9.0
3 2 8	4000.	2.	275.	275.	1300.	1.6	-8.	1.00	9.0
3 2 9	15000:	10.	445.	445.	990.	1.6	-10.	1.00	11.0
3 310	12000.	8.	285:	285:	790.	1.7	-10.	1.00	11.0
3 311	24000.	16.	1095.	1095.	0.	1.7	-2.	1.00	11.0
3 312	16000.	16.	625.	625.	300.	1.7	5.	0.95	13.0
3 313	27000.	27.	990.	990.	1390.	1.7	10.	0.85	13.0
3 314	15000.	15.	570.	570.	3660.	1.8	10.	0.90	13.0
3 318	26000.	13.	520.	520.	790.	1.8	5.	0.90	9.0
3 321	30000.	15.	1095.	1095.	300.	1.8	15.	0.80	9.0
3 322	6000.		170.	170.	2480.	1.8	12.	1.00	5.0
3 323	105000:	3::.	900.	900.	2870.	1.8	10.	1.00	5.0

4 1 1	65000.	26.	485.	485.	0.	1.9	5.	1.00	7.0
4 1 3	57500.	23.	820.	820.	265.	1.9	5.	1.00	7.0
414	40000.	16.	525.	525.					
4 2 5	22500.	9.	415.	415..	20990.	1.9 1.6	-3. 10.	1.00 1.00	7.0 7.0
4 2 6	12500.	5.	190:	600.	600.	1.6	12.	1.00	7.0
427	90000.	45.	630.	630.	0.	1.6	-2.	1.00	9.0
4 2 8	4000.	2.	275.	275.	1300.	1.6	-8.	1.00	9.0
4 2 9	15000.	10.	445.	445.	790. 990.	1.6	-10.	1.00	11.0
4 310	12000.	8.	285:			1.7			
4 311	24000.	16.	1095.	1095.	0.	1.7	-10. -2.	1.00 1.00	11.0 11.0
4 315	6000.	6.	490.	490.	300.	1.7			
4 319	10000.	5.	270.	270.	790.	1.7	-5. -5.	0.95 0.90	13.0 9.0
4 416	37000.	37.	900.	900.	500.	1.5			
4 417	15000.	15.	450.	450.	0.	1.5	-4. -5.	0.90	13.0 13.0
4 420	16000:	8.	335.	335.	2370.	1.5	3.	0.80	9.0
4 421	30000.	15.	1170.	1170.	200.	1.5	4.	0.80	9.0
4 422	6000.	2.	170.	170.	2820.	1.5	4.	1.00	5.0
4 423	105000:	35.	720.	720.	150.	1.5	6.	1.00	5.0

0

1 1 1 1	400.	400.
1 1 1 2	460.	460.
1 1 2 1	450.	450.
1 1 2 2	470.	470.
1 1 4 1	450.	450.
1 1 4 2	470:	470:
1 1 5 1	450.	450
1 1 5 2	470.	470:
1 1 7 1	460.	460.
1 1 7 2	500.	500.
1 1 8 1	400.	400.
1 1 8 2	420.	420.
1 1 9 1	510.	510.
1 1 9 2	550.	550.
1 110 1	460.	460.
1 110 2	490.	490.
1 111 1	500.	500.
1 111 2	520.	520.
1 112 1	450.	450.
1 112 2	490:	490.
1 113 1	450.	450.
1 1 13 2	490.	490.
1 1 14 1	450.	450.
1 114 2	490.	490.
1 118 1	450.	450.
1 118 2	490.	490.
1 121 1	450.	450.
1 121 2	490:	490.
1722 1	450.	450.
1 122 2	490.	490.
1 123 1	450.	450.
1 123 2	490.	490.
2 1 1 1	400.	400.
2 1 1 2	460.	460.
2 1 3 1	450.	450.
2 1 3 2	470.	470.
2 1 4 1	450.	450.
2 1 4 2	470.	470.

2	2	5	1	400.	400.
2	2	5	2	420.	420.
2	2	6	1	400.	400.
2	2	6	2	420.	420.
2	2	7	1	460.	460.
2	2	7	2	500.	500.
2	2	8	1	400.	400.
2	2	8	2	420.	420.
2	2	9	1	510.	510.
2	2	9	2	550.	550.
2	2	10	1	460.	460.
2	2	10	2	490.	490.
2	2	11	1	500.	500.
2	2	11	2	520.	520.
2	2	12	1	450.	450.
2	2	12	2	490.	490.
2	2	13	1	450.	450.
2	2	13	2	490.	490.
2	2	14	1	450.	450.
2	2	14	2	490.	490.
2	2	18	1	450.	450.
2	2	18	2	490.	490.
2	2	21	1	450.	450.
2	2	21	2	490 .	490.
2	2	22	1	450.	450.
2	2	22	2	490.	490.
2	2	23	1	450.	450.
2	2	23	2	450.	450.
3	1	1	1	400:	400:
3	1	1	2	460.	460.
3	1	3	1	450.	450.
3	1	3	2	470.	470.
3	1	4	1	450.	450.
3	1	4	2	470:	470:
3	2	5	1	400.	400.
3	2	5	2	420.	420.
3	2	6	1	400.	400.
3	2	6	2	420.	420.
3	2	7	1	460.	460.
3	2	7	2	500.	500.
3	2	8	1	400.	400.
3	2	8	2	420:	420.
3	2	9	1	510.	510.
3	2	9	2	550.	550.
3	3	10	1	460.	460.
3	3	10	2	490.	490.
3	3	11	1	500.	500.
3	3	11	2	520.	520.
3	3	12	1	450.	450.
3	3	12	2	490.	490.
3	3	13	1	450.	450.
3	3	13	2	490.	490.
3	3	14	1	450.	450.
3	3	14	2	490.	490.
3	3	18	1	450.	450.
3	3	18	2	490.	490.
3	3	21	1	450.	450.

```
3   3 21   2     490.     490.
3   3 22   1     450.     450.
3   3 22   2     490.     490.
3   3 23   1     450.     450.
3   3 23   2     450.     450.
4     1 1  1     400.     400:
4     1 1  2     460.     460.
4   1   3  1     450.     450.
4 1 3      2     470.     470.
4   1   4  1     450.     450.
4 7 4      2     470.     470:
4   2   5  1     400.     400.
4   2   5  2     420.     420.
4   2   6  1     400.     400.
4   2   6  2     420.     420.
4   2   7  1     460.     460.
4   2   7  2     500.     500.
4   2   8  1     400.     400.
4   2   8  2     420.     420.
4   2   9  1     510.     510.
4   2   9  2     550.     550.
4   310    1     460.     460.
4   310    2     490.     490.
4   311    1     500.     500.
4   311    2     520.     520.
4   315    1     450.     450.
4   315    2     490.     490.
4   3 19   1     420.     420.
4   3 19   2     470.     470.
4   416    1     430.     430.
4   416    2     460.     460.
4   417    1     440.     440.
4   417    2     480.     480.
4   420    1     450.     450.
4   420    2     490.     490.
4   421    1     490.     490.
4   421    2     520.     520.
4   422    1     450.     450.
4   422    2     500.     500.
4   423    1     470.     470.
4   423    2     510:     510.
1 1 0.95
2 1 0.95
2 20.90
3 1 0.95
3 2 0.90
3 3 0.85
4 1 0.95
4 2 0.90
4 3 0.85
4 4 0.80
1      120.0
3      600.0
//
```

Appendix 7—Harvesting Example Problem Output Data

```
TITLE 14-S-T  RUN=      HYPOTHETICAL HARVESTING EXAMPLE: 4 METHCDS
 NUUBER OF METHODS= 4
  NUMBER OF DOZERS=    1
NUMBER OF   SKIDDERS= 2
  NUMBER OF TRUCKS= 2
   LP ANALYSIS CODE = 0
     LP  CUTPUT  CODE=  0
# USER CCNSTRAINTS= 2
HARVEST VOLUME=                            567500.  INT. BOARC FEET
PRICE IN SELLING UNITS ($)=                  95.00
HOURLY LANDING MOVE COST ($)=                50.63
DISTANCE FROM WOODS EDGE TO MILL(MILES)=     39.5

*******************************
DOZER  EOZEP   DOZER   HOURLY
LUMBER   UP    EFFIC    COST

     1   72.   0.70    21.63

*******************************
                       21.63


****************************************************
                                             SKIDDER
SKIDDER     SKIDDER     SKIDDER   SKIDDER    HOURLY
NUMBER    HORSEPOWER    WEIGHT    EFFIC       COST
     1
     2     90. 70.     16675. 14175.   0.80     22.30 19.05

****************************************************
                                              41.35


*************************************************************************
       ** NON-WOODS **  ***** WOODS ****
       TRAVEL    TRAVEL    TRAVEL    TRAVEL    FIXED
       EMPTY     LOADED    EMPTY     LOADED    TIME                CYCLE     TRUCK
TRUCK  SPEED     SPEED     SPEED     SPEED     PER     TRUCK       TRUCK     HOURLY
NUMBER  MPH       MPH       MPH       MPH      1.040   EFFIC       VOLUME    COST
  1
  2   34.00 34.00  26.00 28.03  8.30 6.30  5.30  15.00 15.00  0.80 3.83  1800.00  20.50 19.56

*************************************************************************
                                                                          40.00
```

****

METHOD NUMBER	NUMBER ROAD SEGMENTS	NUMBER OF LANDINGS
1	1	1
2	5	2
3	7	3
4	9	4

****

****

METHOD NUMBER	LANDING NUMBER	NUMBER OF AREAS	MAXIMUM AREA CODE NUMBER
1	1	16	23
2	1	3	4
2	2	14	23
3	1	3	4
3	2	5	9
3	3	9	23
4	1	3	4
4	2	5	9
4	3	4	19
4	4	6	23

****

****

METHOD NUMBER	SEGMENT NUMBER	DOZER NUMBER	ROAD LENGTH	ROAD WIDTH	ROAD SLOPE	SIDE SLOPE	CUT SLOPE RATIO	FILL SLOPE RATIO	ROAD TYPE CODE	CUBIC YARDS	ACRES CLEARED	SEGMENT HOURS	SEGMENT COST	METHOD HOURS	METHOD COST
1	1	1	350.	13.c	-10.	10.	1.50	1.50	100.	46.9	0.1	1.9	170.07		
1			350.							46.9	0.1			1.9	170.
2	1		350.	15.0	-JO.	JO.	1.30	1.30	100.	46.9	0.1	7.9	170.07		
2	2	1	450.	15.0	-9.	15.	1.30	1.50	150.	99.2	0.2	7.8	169.00		
2	3	1	325.	15.0	-JO.	12.	1.50	1.50	100.	54.2	0.1	7.1	167.38		
2	4	1	800.	15.0	-13.	JZ.	1.50	1.50	150.	133.3	0.3	12.7	274.67		
2	3		600.	14.0	-8.	JO.	1.50	1.50	100.	70.0	0.2	13.0	286.23		
2			2525.							403.6	1.0			49.1	1061.
3	1	1	350.	15.0	-JO.	JO.	1.50	1.50	100.	46.9	0.1	7.9	170.07		
3	2	1	450.	15.0	-3.	15.	1.50	1.50	150.	95.2	0.2	7.n	169 .oo		
3	3	1	225.	15.0	-10.	12.	1.50	1.50	100.	54.2	0.1	7.7	167.38		
3	4	1	800.	15.0	-10.	12.	1.3"	1.50	150.	133.3	0.3	12.7	274.67		
3	5	1	600.	14.0	-8.	10.	1.50	1.50	100.	70.0	0.2	13.0	280.23		
3	6	1	700.	14.0	-JO.	a.	1.50	1.30	150.	63.1	0.3	9.4	202.73		
3	7	1	650.	13.u	-15.	20.	1.50	1.50	100.	158.8	0.3	16.7	360.69		
3			7473.							623.5	1.6			75.1	1625.
4	1	1	350.	15.0	-10.	10.	1.50	1.50	100.	46.9	0.1	7.9	170.07		
4	2	1	450.	J3.C	-e.	15.	1.50	1.50	150.	99.2	0.2	7.8	169.00		
4	3	1	325.	J5.J	-10.	12.	1.50	1.30	100.	34.2	0.J	7.7	167.38		
4	4	1	300.	15.0	-10.	12.	1.50	1.50	150.	133.3	0.3	12.7	274.61		
4	5	1	600.	14.0	-8.	JP.	1.50	1.30	100.	70.0	0.2	13.0	280.23		
4	6	1	700.	14.3	-10.	8.	1.50	1.30	150.	63.J	0.3	9.4	202.73		
4	7	1	650.	13.0	-15.	20.	1.50	1.50	100.	158.8	n.7	16.7	360.69		
4	3	1	1230.	12.0	-12.	15.	1.50	1.50	100.	176.3	0.4	27.1	587.16		
4	9	1	1430.	12.0	-6.	10.	1.50	1.30	100.	141.3	0.3	32.3	698.43		
4			6113.							943.3	2.6			134.6	2910.

****

METHOD NUMBER	LANDING NUMBER	DISTANCE FROM BOUNDARY	LANDING SIZE ACRES	AVERAGE CUT DEPTH	DOZER HP	HOURLY DOZER COST	EFFIC CODE	LANDING BUILDING HOURS	LANDING BUILDING COST	SYSTEM MOVE HOURS	SYSTEM MOVE COST	WEIGHTED BUILDING & MOVING HOURS	METHOD MOVE & LANDING COST
1													
1	1	350.	1.5	0.3	72.	21.63	1.00	2.60	56.27	0.0	0.00	3.71	56.27
2	1	350.	0.6	0.3	72.	21.63	1.00	1.04	22.51	0.0	0.00		
2	2	2525.	1.5	(1.4	72.	21.63	0.90	3.10	67.13	2.0	101.26		
2												2.64	'90.90
3	1	350.	0.6	0.3	72.	21.63	1.00	1.04	22.51	0.0	0.00		
3	2	2525.	0.8	C.4	72.	21.63	0.90	1.66	35.80	2.Q	101.26		
3	3	3875.	1.5	0.4	72.	21.63	1.00	2.19	40.42	1.8	91.13		
3												4.31	311.13
4	1	350.	0.6	c.3	72.	21.63	1.00	1.04	22.51	0.0	0.00		
4	3	2525.	0.3	G.4	72.	21.63	0.90	1.66	35.80	2.0	101.26		
4	[illegible]	3875.	0.5	0.4	72.	21.63	1.00	1.68	36.25	1.8	91.13		
4		6775.	1.2	0.3	72.	21.63	0.80	2.60	54.27	2.2	1'1.39		
4												4.29	494.62

METHOD NUMBER	LANDING NUMBER	AREA NUMBER	AREA VOLUME	AREA ACRES	MINIMUM SKIDDING DISTANCE	MAXIMUM SKIDDING DISTANCE	FIXED SKIDDING DISTANCE	SKIDDING CORRECTION FACTOR	TRAIL TRAVEL DIRECTION SLOPE LOADED (%)	AREA DIFFICULTY FACTOR	FIXED TIME CYCLE
1	1	1	65000.	26.	415.	485.	0.	1.90	5.	1.00	7.0
1	1	2	70000.	28.	1005.	1005.	265.	1.90	-2.	1.00	7.0
1	1	4	40000.	16.	525.	525.	2080.	1.90	-3.	1.00	7.0
1	1	5	22500.	9.	415.	415.	3700.	1.90	-5.	1.00	1.5
1	1	7	90000.	45.	1180.	1180.	1200.	1.40	-10.	1.00	9.0
1	1	8	4000.	2.	275.	27s.	4000.	1.40	-8.	0.90	9.0
1	1	9	15000.	10.	840.	840.	3000.	1.40	-10.	1.00	11.0
1	1	10	12000.	e.	285.	285.	4950.	1.40	-2.	1.00	11.0
1	1	11	24000.	16.	1095.	1095.	4550.	1.40	5.	0.90	11.0
1	1	12	16000.	16.	625.	425.	5050.	1.50	10.	0.80	13.0
1	1	13	27000.	27.	590.	590.	6230.	1.50	10.	0.90	13.3
1	1	14	15000.	15.	575.	570.	aooo.	1.50	5.	0.90	13.0
1	1	18	26000.	13.	520.	520.	5740.	1.50	15.		9.0
1	1	21	30000.	15.	1095.	1095.	5050.	1.70	12.	0.80	9.0
1	1	22	6000.		170.	170.	7700.	1.70	10.	1.00	5.0
1	1	23	105000.	3::	500.	900.	7225.	1.70	10.	1.00	5.0
2	1	1	65000.	26.	485.	485.	0.	1.60	5.	1.00	7.0
2	1	3	57500.	23.	820.	820.	265.	1.60	5.	1.00	7.0
2	1	4	40000.	16.	525.	525.	2oQQ.	1.60	-3.	1.00	7.0
2	2	5	22500.	9.	41s.	415.	990.	1.60	'0.	1.00	1.0
2	2	b	12500.	5.	'90.	'90.	600.	1.60	12.	1.00	7.0
2	2	7	WOOF.	45.	630.	630.		1.60	-2.	1.00	9.0
2	2	8	4000.	2.	275.	275.	130::	1.60	--	1.00	9.0
2	2	9	15000.	10.	445.	445.	990.	1.60	-10.	1.00	11.0
2	2	10	12000.	8.	285.	285.	1680.	1.40	-10.	1.00	'1.0
2	2	11	24000.	16.	1095.	1095.	1290.	3.40	-2.	1.00	IA.0
2	2	12	16000.	16.	625.	625.	1780.	1.40	5.	0.90	13.0
2	2	13	27000.	27.	990.	990.	2670.	1.40	10.	0.co	13.0
2	2	14	15000.	15.	570.	57G.	5050.	1.90	10.	0.90	13.0
2	2	18	26009.	13.	520.	520.	2080.	1.50	5.	0.90	9.0
2	2	21	30000.	15.	1095.	1095.	1880.	1.50	15.	0.80	9.0
2	2	22	6000.		'70.	170.	3660.	1.50	12.	1.00	5.0
2	7	a3	105000.	3;:	900.	900.	4260.	1.50	10.	1.00	5.0
3	1	1	65000.	26.	495.	485.	0.	1.90	5.		7.0
3	1	3	57500.	23.	820.	820.	265.	1.90	5.	1.00	7.0
3	1	4	40000.	lb.	525.	525.	20110.	1.90	-3.	1.00	7.0
3	2	5	22500.	5.	415.	415.	990.	1.60	10.		7.0
3	2	6	12'00.	5.	190.	600.	600.	1.60	12.	1.00	7.0
3	2	1	90000.	45.	630.	630.	0.	1.60	-2.	1.00	9.0
3	2	8	4000.	2.	275.	21s.	1300.	1.60	-8.	1.00	9.0
3	2	9	15000.	10.	445.	449.	990.	1.60	-10.		11.0
3	3	10	12000.	8.	285.	285.	750.	1.70	-10.	1.00	11.0
3	3	II	24000.	16.	1095.	1095.	n.	1.70	-2.	1.00	11.0
3	3	12	16000.	lb.	625.	625.	300.	1.70	5.	0.90	13.0
3	3	13	27000.	27.	590.	550.	1390.	1.70	10.	0.80	13.0
3	3	14	15000.	15.	570.	570.	3660.	1.80	10.	0.90	13.0
3	3	18	26000.	13.	520.	520.	790.	1.80	5.	0.90	9.0
3	3	21	30000.	15.	'095.	1099.	300.	1.80	'5.	0.e0	9.0
3	3	22	6000.	2.	170.	170.	2480.	1.80	12.	1.30	5.b
3	3	23	105000.	33.	900.	900.	2870.	1.80	10.	1.00	5.0
4	1	1	65000.	26.	485.	485.	0.	1.90	5.	1.00	7.0
4	1	3	57500.	23.	820.	820.	265.	1.90	5.	1.00	7.0
4	1	4	40030.	16.	525.	525.	20to.	1.90	-3.	1.00	7.0
4	2	5	22500.	5.	415.	415.	990.	1.60	10.		7.0
4	2	6	12500.	5.	190.	600.	600.	1.60	'2.	1.00	7.0
4	2	7	90000.	43.	630.	630.	0.	1.60	-2.	1.00	9.0
4	2	8	4000.	2.	275.	275.	1300.	1.60	-8.	1.00	9.0
4	2	9	15000.	10.	445.	445.	990.	1.60	-10.	1.00	11.0
4	3	10	12000.	8.	285.	265.	790.	1.70	-10.	1.00	11.0
4	3	11	24000.	16.	1095.	1095.	0.	1.70	-2.	1.00	11.0
4	3	15	6000.	t.	490.	450.	300.	1.70	-5.	0.90	13.0
4	3	19	10000.	5.	270.	270.	790.	1.70	-5.	0.90	9.0
4	4	16	37000.	31.	500.	300.	500.	1.50	-4.	0.90	lY.O
4	4	17	15000.	15.	450.	450.		1.50	-5.	0.90	13.0
4	4	20	16000.	8.	335.	335.	237::	1.50	3.	0.80	9.0
4	4	2'	30000.	'5.	1170.	1170.	200.	1.50	4.	0.80	9.0
4	4	22	6000.	2.	170.	170.	2020.	1.50	4.	1.00	5.0
4	4	23	105000.	35.	720.	720.	150.	1.50	b.	1.00	5.0

*********** ALL SKIDDERS WORKING TOGETHER ***********

METHOD NO	LAND NO	AREA NO	SKID NO	MINIMUM VOLUME SKIDDED	MAXIMUM VOLUME SKIDDED	CYCLE TIME MINUTES	NUMBER OF CYCLES	AREA SKID TIME HOURS	AREA SKIDDING HOURS	LANDING SKIDDING HOURS	LANDING SKIDDING COSTS	METHOD SKIDDING HOURS	METHOD SKIDDING COSTS
1	1	1	1	400.0	400.J	'9.91	'63.	51.21					
1	1	1	2	463.0	460.5	16.51	141.	38.89					
1	1	1							22.10				
1	1	2	1	45fl.0	450.J	32.45	'56.	84.13					
1	1	2	2	470.0	470.0	27.21	'49.	67.54					
1	1	2							37.46				
1	1	4	1	45n.0	450.0	42.8'	89.	63.42					
1	1	4	2	470.0	470.0	35.43	95.	50.25					
1	1	4							28.04				
1	1	5	1	450.0	450.5	58.71	50.	48.93					
1	1	5	2	470.0	470.0	47.97	48.	38.27					
1	1	5							21.47				
1	1	7	1	460.0	460.3	40.05	196.	130.59					
1	1	7	2	500.0	500.0	33.4')	180.	100.48					
1	1	7							56.79				
1	1	8	1	coo .o	400.J	64.21	10.	10.70					
1	1	8	2	420.0	420.0	52.82	14.	8.38					
1	1	8							4.10				
1	1	9	1	510.F	510.J	57.60	29.	28.23					
1	1	9	2	550.n	550.0	47.7'	27.	21.69					
1	1	9							12.27				
1	1	10	1	460.0	460.0	76.40	26.	33.25					
1	1	10	2	490.0	490.0	62.58	24.	25.7'					
1	1	10							'4.50				
1	1	11	1	500.0	500.0	102.74	48.	82.19					
1	1	11	2	520.0	520.0	84.38	46.	64.9'					
1	1	11							36.27				
1	1	12	1	450.0	450.C	121.88	?b.	72.23					
1	1	'2	7	490.0	490.0	101.06	33.	55.00					
1	1	12							31.22				
1	1	13	1	450.0	450.0	136.69	60.	136.69					
1	1	13	2	490.0	490.0	112.57	55.	103.38					
1	1	13							58.86				
1	1	14	1	450.0	450.0	148.72	33.	82.34					
1	1	'4	2	490.0	490.0	121.35	31.	61.91					
1	1	14							33.34				
1	1	14	1	450.0	450.0	131.56	58.	126.69					
1	1	18	2	490.0	490.0	108.37	53.	55.84					
1	1	18							54.56				
1	1	21	1	450.0	450.0	120.20	67.	'33.56					
1	1	21	2	490.0	490.0	98.73	Cl.	100.75					
1	1	21							57.43				
1	1	22	1	450.0	450.0	117.11	13.	26.03					
1	1	22	2	490.0	490.0	95.19	'2.	19.43					
1	1	22							'1.12				
1	1	23	1	450.0	450.0	128.61	233.	500.16					
1	1	23	2	490.0	490.0	104.40	214.	372.85					
1	1	23							213.61				
1	1									695.75	20769.13		
1												695.75	28769.13

*********** ALL SKIDDERS WORKING TOGETHER ***********

METHOD NO	LAND NO	AREA NO	SKID NO	MINIMUM VOLUME SKIDDED	MAXIMUM VOLUME SKIDDED	CYCLE TIME MINUTES	NUMBER OF CYCLES	AREA SKID TIME HOURS	AREA SKIDDING HOURS	LANDING SKIDDING HOURS	LANDING SKIDDING COSTS	METHOD SKIDDING HOURS	METHOD SKIDDING COSTS
2	1	1	1	400.0	400.0	17.19	163.	44.57					
2	1	1		460.0	460.3	15.12	141.	35.62					
2	1	1							20.18				
2	1	3	1	450.0	450.o	27.00	128.	57.49					
2	1	3	2	470.0	470.0	22.96	'22.	46.82					
2	1	3							25.80				
2	1	4	1	450.0	450.3	40.93	89.	60.64					
2	1	4	2	470.0	470.0	33.53	85.	48.13					
2	1	4							26.83				
2	1									72.02	3011.06		
2	2	5	1	400.0	400.0	28.95	56.	27.14					
2	2	5	2	420.0	420.0	24.62	54.	21.99					
2	2	5							'2.15				
2	2	6	1	400.0	400.0	19.55	3'.	10.18					
2	7	6	2	420.0	420.0	'7.05	30.	8.46					
2	2	6							4.62				
2	2	7	1	460.0	460.0	21.61	196.	70.47					
2	2	7	2	500.0	500.0	18.94	180.	56.32					
2	2	7							31.46				
2	2	8	1	400.0	400.0	21.39	10.	4.73					
2	2	8	2	420.0	420.11	24.26	10.	3.85					
2	2	a							2.12				
2	2	9	1	5'0.0	510.5	30.36	29.	14.88					
2	2	9	2	550.0	550.1	26.17	27.	11.89					
2	2	9							6.61				
2	2	10	1	460.0	460.0	34.21	26.	14.87					
2	2	10	2	490.0	490.0	29.22	24.	11.93					
2	2	10							6.62				
2	2	11	1	3oo.n	500.0	45.40	48.	36.32					
2	2	11	2	520.0	520.0	38.22	4t.	29.40					
2	2	11							'6.25				
2	2	12	1	450.0	450.6	53.58	36.	31.75					
2	2	12	2	490.0	490.0	45.66	33.	24.85					
2	2	12							'3.94				
2	2	13	1	450.0	450.0	87.09	60.	87.09					
2	2	13	2	490.0	490.0	73.10	55.	67.14					
2	2	13							37.91				
2	2	14	1	450.0	450.0	110.70	33.	61.50					
2	2	14	2	490.0	490.0	91.73	31.	46.60					
2	2	14							26.58				
2	2	18	1	450.0	450.0	50.99	58.	49.10					
2	2	19	2	490.0	490.0	42.81	53.	37.36					
2	2	18							il.37				
2	2	21	1	450.0	450.0	74.66	67.	82.96					
2	2	21	2	49n.o	490.0	62.47	61.	t3.74					
2	2	21							36.05				
2	2	22	1	450.0	450.0	58.82	13.	13.07					
2	2	22	2	490.0	490.0	48.47	12.	9.89					
2	2	22							5.63				
2	2	23	1	450.0	450.0	82.00	233.	318.99					
2	2	23	2	450.0	450.0	66.70	233.	259.37					
2	2	23							'43.03				
2	2									364.33	15065.10		
2												437.15	18076.lb
3	1	1	1	400.0	400.0	16.51	163.	51.21					
3	1	1	2	4b0.0	460.0	16.51	141.	38.09					

************ ALL SKIDDERS WORKING TOGETHER ************

METHOD NO	LAND NO	AREA NO	SKID NO	MINIMUM VOLUME SKIDDED	MAXIMUM VOLUME SKIDDED	CYCLE TIME MINUTES	NUMBER OF CYCLES	AREA SKID TIME HOURS	AREA SKIDDING HOURS	LANDING SKIDDING HOURS	LANDING SKIDDING COSTS	METHOD SKIDDING HOURS	METHOD SKIDDING COSTS
3	1	1							22.10				
3	1	1	1	'10.0	450.0	30.0.	128.	64.75					
3	1	3	2	470.0	470.0	25.44	122.	51.36					
3	1	3							28.66				
3	1	4	1	450.0	450.0	52.91	89.	63.32					
3	1	4	2	470.0	470.0	35.43	85.	50.25					
3	1	4							28.04				
3	1									78.80	3259.22		
3	2	5	1	'OP.0	400.0	28.55	56.	27.12					
3	2	5	2	420.0	420.0	24.62	54.	il...					
3	2	5							12.15				
3	2	6	1	400.0	400.0	23.07	31.	12.03					
3	2	6	,	420.0	'20.0	19.96	30.	9.90					
3	2	6							5.43				
3	2	7	1	460.0	'40.0	21.61	196.	70.47					
3	2	7	2	'100.0	500.0	18.54	180.	56.82					
3	2	7							31.46				
3	2	9	1	400.0	400.0	29.29	10.	4.73					
3	2	9	7	'13.0	420.0	24.26	10.	3.85					
3	2	8							2.12				
3	2	9	1	510.0	510.0	30.26	75.	14.08					
3	2	9	2	550.0	550.0	26.11	77.	11.89					
3	2	9							6.61				
3	2									57.77	2388.61		
3	3	10	1	460.0	460.0	25.81	26.	11.22					
3	3	10	2	'90.0	490.0	22.56	2'.	9.21					
3	3	10							[illegible]				
3	3	11	1	500.0	500.0	I? .54	48.	27.1.					
3	3	11	2	520.0	520.0	29.1'	46.	22.3.					
3	3	11							12.27				
3	3	12	I	'S0.0	450.0	35.33	36.	20.96					
3	3	12	2	490.0	450.0	31.02	33.	16.88					
3	3	12							9.35				
3	3	13	1	'T0.0	'51.0	69.85	60.	65.85					
3	3	13	2	590.0	'90.0	59.23	55.	54.39					
3	3	13							30.58				
3	3	14	1	'90.0	'SO.0	87.39	33.	48.55					
3	3	14	2	490.0	'90.0	13.0'	31.	37.25					
3	3	14							21.08				
3	3	18	1	450.0	'50.0	34.84	58.	33.55					
3	3	18	2	490.0	'50.0	29.83	53.	26.39					
3	3	18							14.77				
3	3	21	1	'S0.0	'SO.0	51.88	67.	57.64					
3	3	21	2	490.0	'50.0	'4.03	61.	'4.93					
3	3	21							25.25				
3	3	22	1	'50.0	'50.0	42.71	13.	9.4.					
3	3	22	2	490.0	'90.V	35.47	'2.	7.2.					
3	3	22							4.11				
3	3	23	1	450.0	'SO.0	65.85	233.	256.08					
3	3	23	2	450.0	450.0	53.79	233.	20.. 18					
3	3	23							115.13				
3	3									237.59	5824.48		
3												374.16	15471.31
4	1	1	1	'00.0	'00.0	18.51	163.	51.21					
4	1	1	2	'60.0	'60.0	16.51	141.	39.99					
4	1	1							22.10				
4	1	3	I	'50.0	'50.0	30.01	128.	64.05					

************ ALL SKIDDERS WORKING TOGETHER ************

METHOD NO	LAND NO	AREA NO	SKID NO	MINIMUM VOLUME SKIDDED	MAXIMUM VOLUME SKIDDED	CYCLE TIME MINUTES	NUMBER OF CYCLES	AREA SKID TIME HOURS	AREA SKIDDING HOURS	LANDING SKIDDING HOURS	LANDING SKIDDING COSTS	METHOD SKIDDING HOURS	METHOD SKIDDING COSTS
4	1	3	2	'70.0	570.0	25.44	'22.	51.86					
4	1	3							28 .bb				
4	I	4	1	450.0	450.0	42.9'	89.	63.42					
4	1	4	2	470.0	470.0	35.43	85.	50.25					
4	1	4							28.0.				
4	1									79.90	32S0.22		
4	2	5	1	'00.0	'00.0	28.55	56.	27.14					
4	2	5	2	420.0	'20.0	24.62	54.	21.9.					
4	2	5							12.15				
4	2	6	1	'00.0	400 .o	23.09	31.	12.03					
4	2	6	]	420.0	420.0	19.96	30.	9.90					
4	7	6							5.43				
4	2	7	1	460.0	'60.0	21.61	196.	70.47					
4	2	7	2	500.0	500.0	18.54	180.	56.82					
4	2	7							31.46				
4	2	8	1	400.0	'00 .O	28.39	10.	4.73					
4	2	9	2	420.0	420.0	24.26	10.	3.85					
4	2	[illegible]							2.12				
4	2	9	1	510.0	510.0	30.36	29.	14.88					
4	2	9	2	550.0	S50.U	26.17	27.	11.39					
4	2	9							6.61				
4	2									57.77	2388.61		
4	3	10	1	'40.0	460.0	25.81	26.	11.22					
4	3	'0	2	490.0	490.0	22.56	24.	9.21					
4	3	10							5.06				
4	3	11	1	500.0	500.0	33.9.	48.	21. 15					
4	3	11	2	520.0	520.0	29.11	46.	22.3.					
4	3	11							12.27				
4	3	15	1	450.0	'50.3	30.61	13.	t.eo					
4	3	15	2	'90.0	'90.0	27.09	'2.	1.53					
4	3	15							3.05				
4	3	17	I	'20.0	420.5	26.38	24.	L0.47					
4	3	19	,	• 7a.n	670.0	22.93	21.	8.13					
4	3	19							4.58				
4	3									24.95	'031.06		
4	'	16	1	'30."	430.0	39.56	96.	56.74					
4	4	16	2	460.0	'60.0	34.23	80.	45.89					
4	.	lb							25.37				
4	.	17	1	440.0	" 0 .0	21.23	3'.	14.33					
4	.	17	2	480.0	'10.0	22.17	3'.	11.86					
4	.	17							6.49				
4	.	20	1	'SO.0	455.0	56.55	36.	33.51					
4	4	20	2	'90.0	'90.0	47.44	33.	25.82					
4	.	20							14.58				
4	.	21	1	590.0	'90.0	42.63	61.	43.50					
4	4	21	2	520.0	520.0	36.26	58.	34.86					
4	.	21							'9.35				
4	4	22	1	'50.0	450.0	43.26	13.	9.61					
4	'	22	2	100.0	500 .o	35.74	12.	1. 15					
4	.	22							4.10				
4	4	23	1	• 70.0	470.0	20.52	223.	76.04					
4	4	23	2	110.0	5'0.0	17.37	206.	59.6'					
4	.	23							33.41				
4	.									103.31	4211.99		
4												264.83	10950.56

METHOD NUMBER	LANDING NUMBER	LANDING VOLUME	LANDING ACRES	METHOD VOLUME	METHOD ACRES	PER LANDING: AVERAGE SKIDDING DISTANCE	PER LANDING: AVERAGE FIXED SKIDDING DISTANCE	PER LANDING: WEIGHTED AVERAGE TRAVEL SKIDDING DISTANCE	PER METHOD: AVERAGE SKIDDING DISTANCE	PER METHOD: AVERAGE FIXED SKIDDING DISTANCE	PER METHOD: WEIGHTED AVERAGE TRAVEL SKIDDING DISTANCE
1	1	567500.	283.			686.	'296.	4871.			
1				567500.	283.				bfb.	4296.	4871.
2	1	162500.	65.			610.	792.	1587.			
2	2	405000.	218.			596.	2016.	3212.			
2				567500.	283.				598.	1399.	2747.
3	1	162500.	7[illegible].			610.	782.	1771.			
3	2	144000.	147.			432.	116.	1221.			
3	)	261000.				694.	1398.	3204.			
3				567500.	283.				579.	985.	2290.
4	1	102500.	65.			610.	782.	1771.			
4	3	144000.	II.			432.	776.	1221.			
4		52000.	35.			535.	470.	1524.			
4	4	209000.	112.			624.	1057.	1583.			
4				567500.	293.				550.	759.	1540.

METHOD NUMBER	LANDING NUMBER	TRUCK TRAVEL CORRECTION FACTOR
1	1	'1.99
2	1	0.95
2	2	0.90
3	2	0.95
3	3	0.90
		0.95
4	1	0.95
.	2	0.90
4	3	0.85
A	4	0.80

METHOD NUMBER	LANDING NUMBER	TRUCK NUMBER	CYCLE TIME HOURS	NUMBER Of LOADS	TRUCK TIME HOURS	ALL TRUCKS WORKING TOGETHER: LANDING TRUCKING HOURS	ALL TRUCKS WORKING TOGETHER: LANDING TRUCKING COST	ALL TRUCKS WORKING TOGETHER: METHOD TRUCKING HOURS	ALL TRUCKS WORKING TOGETHER: METHOD TRUCKING COST
1	1	1	2.82	315.3	889.62				
1	1	2	2.93	2e3.8	830.65				
1	1					429.56	17182.48		
1								429.56	17182.48
2	1	I	2.82	90.3	254.74				
2	1	2	2.93	t1.3	237.85				
2	1					123.00	4520.13		
2	2	1	2.95	225.5	b72.74				
2	2	2	3.10	202.5	626.12				
2	2					324.83	12993.30		
2								447.83	17913.40
3	1	1	2.82	90.3	254.14				
3	1	2	2.93	81.3	237.85				
3	1					123.00	4920.10		
3	2	1	2.99	30.0	239.20				
	2	2	?. 10	12.0	223.33				
3	2					115.50	4619.34		
3	3	1	3.10	145.0	449.80				
3	3	2	3.22	130.5	419.55				
3	3					217.18	8687.21		
3								455.68	18227. lb
4	1	1	2.82	90.3	254.74				
4	1	2	2.93	81.3	237.85				
4	1					123.00	4920.10		
4	2	1	2.99	80.0	239.20				
4	2	2	3.10	72.0	223.33				
4	2					115.50	4619.04		
4	3	1	3.10	28.9	89.61				
4	3	2	3.22	26.0	83.67				
4	3					43.21	1730.79		
4	4	1	3.35	116.1	368.55				
4	4	2	3.47	104.5	362.75				
4	4					187.60	7504.20		
4								469.37	18774.91

CONSTRAINT CODE
1= ROAD HR
2= LAND HR
3= SKID HR
4= TRUK HR

CONSTRAINT CODE	UPPER BOUND VALUE
1	120.
3	600.

METHOD SUMMARY

METH NO	ROAD CONSTRUCTION HOURS	$$$	$/VOL	LANDING CONSTRUCTION AND SYSTEM MOVING HOURS	$$$	$/VOL	SKIDDING HOURS	$$$	$/VOL	TRUCKING HOURS	$$$	$/VOL	TOTAL METHOD HARVESTING COSTS	METHOD HARVESTING UNIT COSTS
1	9.	170.	0.	1.	56.	0.	696.	20169.	51.	430.	17182.	30.	46177.95	61.37
2	49.	1061.	2.	3.	191.	0.	431.	18076.	32.	448.	17913.	32.	37241.81	65.62
3	75.	1625.	3.	4.	311.	1.	374.	15471.	27.	456.	18227.	32.	35634.38	62.79
4	135.	2910.	5.	6.	455.	1.	265.	10551.	19.	469.	16775.	33.	33090.45	58.31

ITERATION NO= 1

CB	BASIS	SELLING PRICE $ (Y)	METHOD 1 (M1)	METHOD 2 (M2)	METHOD 3 (M3)	METHOD 4 (M4)	$/HR ROADS (Z1)	$/HR LAND (Z2)	$/HR SKIL (Z3)	$/HR TRUCK (Z4)	RIGHT HAND CONSTANTS
CJ		95.00					-21.63	-72.26	-41.35	-40.00	
95.00	X10	1.00	-567.50	-567.50	-567.50	-567.50	0.00	0.00	0.00	0.00	0.00
0.00	X11	0.00	7.86	49.01	75.12	134.55	-1.03	0.00	0.00	0.00	0.00
[illegible]	X12	[illegible]	[illegible]	2.64	[illegible]	6.25	0.00	-1.00	0.00	0.00	0.60
0.00	X13	0.00	695.75	437.15	374.16	264.63	0.00	0.00	-1.00	0.00	0.00
0.00	X14	0.00	429.55	447.63	455.68	469.37	0.00	0.00	0.00	-1.00	0.00
-21.63	X15	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	567.50
-72.26	X16	0.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	1.00
-41.35	X17	0.00	0.00	0.00	0.00	0.00	1.03	0.00	0.30	0.00	120.00
-40.00	X18	0.00	[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	600.00
C-BAR ROW		35.50	0.00	0.00	0.00	0.00	-21.63	-72.26	-41.35	-40.00	Z = 0.

AFTER 18 ITERATIONS THE OPTIMUM SOLUTION CONSISTED OF :

METHOD #	METHOD PROPORTION	ROAD CONST HOURS	ROAD CONST COSTS	LANDING CONST AND SYSTEM HOURS	LANDING CONST AND SYSTEM COSTS	SKIDDING HOURS	SKIDDING COSTS	TRUCKING HOURS	TRUCKING COSTS	TOTAL METHOD COSTS
4	0.76	101.6	2198.	4.8	343.	200.	8269.	354.5	14178.	24989.
3	0.24	18.4	398.	1.1	76.	92.	3788.	111.6	4463.	8725.
TOTALS:	1.00	120.0	2596.	5.8	419.	292.	12057.	466.0	18641.	33713.

(A) TOTAL DELIVERD PRICE OF HARVESTED TIMBER: 53913. UNIT PRICE: 95.00
(B) TOTAL HARVESTING COSTS (THOSE CONSIDERED): 33713. UNIT COSTS: 59.41

DIFFERENCE: (A)-(B): 20199. 35.59

ITERATION NO= 18

CB	BASIS	SELLING PRICE $ (Y)	METHOD 1 (M1)	METHOD 2 (M2)	METHOD 3 (M3)	METHOD 4 (M4)	$/HR ROADS (Z1)	$/HR LAND (Z2)	$/HR SKID (Z3)	$/HR TRUCK (Z4)	RIGHT HAND CONSTANTS
CJ		95.00					-21.63	-72.26	-41.35	-40.00	
0.00	X 1	1.00	0.00	0.00	0.00	-0.00	-0.00	-0.00	-0.00	-0.00	567.50
0.00	Y 7	-0.00	1.28	0.79	0.00	-0.00	-0.00	1.00	-0.00	-0.00	5.81
0.00	Y 8	-0.00	-197.09	-15.05	0.00	-0.00	-0.00	-0.00	1.00	-0.00	291.59
[illegible]	X 9	-0.00	10.62	1.84	0.00	-0.00	-0.00	-0.00	-0.00	1.00	466.02
-40.00	X19	-0.00	197.83	15.08	4.00	-4.00	-0.00	[illegible]	[illegible]	-0.00	306.M
[illegible]	X 5	-0.00	-1.13	-0.44	0.00	1.00	-3.00	-0.30	-0.00	-0.00	0.76
[illegible]	X [illegible]	0.00	[illegible]	1.44	1.00	0.00	0.00	0.00	0.00	0.00	[illegible]
-72.26	[illegible]	-0.00	[illegible]	0.00	0.00	-0.00	-0.00	-0.00	[illegible]	-0.00	[illegible]
0.00	[illegible] 6	-0.00	0.00	[illegible]	[illegible]	[illegible]	1.00	-0.03	-0.30	-0.00	120.00
C-BAR ROW		0.00	-7665.56	-492.68	0.00	0.00	0.00	0.00	0.00	0.00	Z = 20199.

ABOVE VALUES IN C-BAR ROW
ARE PENALTY COSTS

ABOVE VALUES IN C-BAR ROW
ARE SHADOW PRICES

SENSITIVITY ANALYSIS

NOTE: VARIABLE CODE NUMBERS USED IN SENSITIVITY ANALYSIS ARE NOT EASY TO CORRELATE WITH OUTPUT COLUMNS AND ROWS FROM LP MATRIX

USERS FAMILIAR WITH LP SHOULD MAKE CHANGES IN INPUT COSTS (CJ) AND RESOURCE LIMITS (EJ) TO BECOME FAMILIAR WITH THE SENSITIVITY ANALYSIS AS IT APPLIES TO THE CONVEX-ISOQUANT-METHOD FORMULATION USED IN L-O-S-T

SHADOW PRICES ARE CHANGE IN OBJECTIVE FUNCTION VALUE PER UNIT CHANGE IN RIGHT HAND SIDE CONSTRAINTS.

PENALTY COSTS ARE CHANGE IN OBJECTIVE FUNCTION VALUE PER UNIT INCREASE IN NON-BASIC VARIABLES.

RANGES ON C(J) REPRESENT LIMITING VALUES OF COST COEFFICIENTS THAT WILL NOT CHANGE THE OPTIMUM SOLUTION

RANGES ON B(I) REPRESENT LIMITING VALUES OF RIGHT HAND SIDE CONSTRAINTS THAT WILL NOT CHANGE OPTIMUM BASIC VARIABLES.

NON-BASIC VARIABLES	PENALTY COST
10	-67.947
11	-64.426
12	-72.260
13	-41.350
14	-40.000
15	-27.053
17	-42.756
2	-7669.563
3	-492.884

ROW NUMBER	SHADOW PRICES
1	a.000
2	a.cca
3	0.000
4	0.000
5	0.000
6	0.000
7	a.000
8	0.000
9	0.000

RANGES ON NON-BASIC C(J)

VARIABLE	LOWER LIMIT
10	b7.541
11	64.426
12	72.260
13	41.350
14	40.000
15	27.053
17	42.756
2	7665.563
3	492.884

RANGES ON BASIC C(J)

VARIABLE	LOWER LIMIT	UPPER LIMIT
16	-38559.850	15352.200
18	-23.267	30.446
1	67.947	999999.000
4	-341.br.4	2543.590
5	-2543.590	1124.623
6	-64.425	17372.890
7	-693.435	0.000
8	-71.932	-13.083
9	-74.861	0.000

RANGES ON B(I)

	LOWER LIMIT	UPPER LIMIT
1	567.500	567.500
2	'74.124	132.501
3	-999999.000	1.923
4	504.219	501.998
5	-999999.000	440.392
6	-0.000	-0.000
7	1.000	999999.000
8	274.124	132.501
9	504.219	999999.000

Appendix 8-L-0-S-T Program Listing

```
//LOST     JOB (UFS26JK,153),'KOGER',NOTIFY=UFS26JK,MSGCLASS=A,
//         MSGLEVEL=(1,1)
/*ROUTE PRINT LOCAL
/*JOBPARM T=21,L=40K
// EXEC WATFIV
//WATFIV.SYSIN DD *
/JOB KOGER,PAGES=50,S=1000000,TIME=25
      DIMENSION DZRHP(5),DZREF(5),DZRHC(5),SKDHP(10),SKDWT(10),
     1SKDEF(10),SKDHC(10),TKTENW(10),TKTLNW(10),
     2TKTEWD(10),TKTLWD(10),TKFTPC(10),TKEF(10),TKVOL(10),
     3TKHC(10),ILAND(10),ATITLE(16),
     4INRSBM(20),JNAREA(4,10),DSFTB(4,10)
      DIMENSION AREAV(4,8,25),AREAA(4,8,25),AREAMN(4,8,25),
     1AREAMX(4,8,25),AREAFD(4,8,25),AREACF(4,8,25),
     2AREATS(4,8,25),AREADI(4,8,25),AREAFT(4,8,25),
     3VOLML(4,10),VOLBM(4),TKTCF(4,10)
     4,AREA(4,8,25),VOLMA(4,10),ACRBM(4)
     5,ASKDBL(4,8),FSKDBL(4,8),WSKDBL(4,8),ASKDBM(4),
     6FSKDBM(4),WSKDBM(4)
      DIMENSION LOGMET(11,20),SUM(10,10,14),SUMMET(2,50),CI(25)
      COMMON C(25),P(25),CMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
     1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
     2,B(25),CC(25),JVAR(25),IARR(4),PROP(4),RC(4),LD(4),SK(4),
     3TK(4)
      REAL LOGMET,LD,LAMOMC
CJK
CJK  CJK COMMENT CARDS BY JERRY KOGER
CJK  CWC COMMENT CARDS BY WADE CULVER
CJK  C   COMMENT CARDS BY RAVINDRAN, ETC.
CJK
CJK
CJK
CJK       L-o-S-T IS DIVIDED INTO 2 SECTIONS; THE FIRST SECTION
CJK       CALCULATES LOGGING COSTS AND THE SECOND SECTION USES
CJK       THESE COSTS AS INPUT FOR THE LINEAR PROGRAM
CJK
CJK
CJK
CJK        ########  SECTION 1  #######################
CJK
CJK
CJK
CJK  CTRAD CONVERTS DEGREES TO RADIANS; CTDEG CONVERTS RADIANS
CJK  TO DEGREES;  KR=5 FOR READ
CJK  READ(KR,YY); KW=6 FOR WRITE  WRITE(KW,ZZ)
CJK
      CTRAD = 0.01745329
      CTDEG = 57.29578
      KR=5
      KW = 6
CJK
CJK
CJK CONPTB=CONVERSION POUNDS TO BOARD FEET,VALUE OF 0.11951
CJK TAKEN FROM TVA TECHNICAL NOTE B46, 1982 BY JERRY KOGER
CJK "LOG LOADING METHODS AND COSTS IN THE TENNESSEE VALLEY
CJK  REGION   PAGE 20
CJK  CONBTB=CONVERSION FROM BOARD FEET TO BOARD FEET 1/4 INT
CJK  CONCTB=CONVERSION FROM CORDS TO BOARD FEET
CJK  CONUTB= CONVERSION FROM CUBIC FEET TO BOARD FEET
CJK   THESE CONVERSIONS ARE ONLY USED IN SKIDDING TIME EQUATIONS
CJK
      CONPTB=0.11951
      CONBTB=1.0
      CONCTB=687.2746
      CONUTB=5.7947
CJK
CJK
CJK  ***************** CARD TYPE 1 ******************************
CJK
CJK
      READ(KR,70) (ATITLE(ITR),ITR=1,16)
   70 FORMAT(16A4)
      WRITE(KW,80) (ATITLE(ITW),ITW=1,16)
   81 FORMAT(1H1,/,2X,'TITLE L-U-S-T RUN=',4X,16A4)
CJK

CJK
CJK  ***************** CARD TYPE 2 ********************************
CJK
CJK
CJK  NMETH=# OF METHODS; NOZR=#OF DOZERS; NSKD=# OF SKIDDERS;
CJK  NTRK= # OF TRUCKS; ICTRAT=# OF USER SUPPLIED CONSTRAINTS
CJK  FOR LP ANALYSIS;  LPCDE=LP OUTPUT MATRIX DEBUG CODE
CJK
      READ(KR,90)NMETH,NOZR,NSKD,NTRK,ICTRAT,ILPANA,LPCDE
   90 FORMAT(I2,1X,I2,1X,I2,1X,I2,1X,I1,1X,I1,1X,I1)
      WRITE(KW,100)NMETH,NOZR,NSKD,NTRK
  100 FORMAT(3X,'NUMBER OF METHODS=',2X,I3,/,4X,'NUMBER OF',
     11X,'DOZERS=',2X,I3,/,2X,'NUMBER OF SKIDDERS=',2X,I3,/,
     24X,'NUMBER OF TRUCKS=',2X,I3)
      WRITE(KW,125)ILPANA,LPCDE,ICTRAT
  125 FORMAT(4X,'LP ANALYSIS CODE=',3X,I2,/,6X,'LP OUTPUT CODE=',
     13X,I2,/,2X,'# USER CONSTRAINTS=',3X,I2)
      M=ICTRAT+5
      M2=NMETH+ICTRAT+10
CJK
CJK
CJK  ZERO OUT AREA VOLUME ARRAY
CJK
CJK
      DO 150 IZAVM=1,NMETH
      DO 140 IZAVL=1,8
      DO 130 IZAVA=1,25
      AREAV(IZAVM,IZAVL,IZAVA)=0.0
  130 CONTINUE
  140 CONTINUE
  150 CONTINUE
CJK
CJK
CJK
CJK  ZERO OUT SELECTED ARRAYS USED IN LP SECITON OF LOST
CJK
      DO 170 IDL21=1,25
      DO 160 IDL22=1,25
      A(IDL22,IDL21)=0.0
  160 CONTINUE
  170 CONTINUE
      DO 185 IZOUT1=1,11
      DO 180 IZOUT2=1,20
      LOGMET(IZOUT1,IZOUT2)=0.0
  180 CONTINUE
  185 CONTINUE
      DO 190 IZOUT3=1,25
      CI(IZOUT3)=0.0
      C(IZOUT3)=0.0
      P(IZOUT3)=0.0
      CMZ(IZOUT3)=0.0
      ZJ(IZOUT3)=0.0
      IVAR(IZOUT3)=0.0
      PCOST(IZOUT3)=0.0
      SHADO(IZOUT3)=0.0
      CL(IZOUT3)=0.0
      CU(IZOUT3)=0.0
      CUP(IZOUT3)=0.0
      CLO(IZOUT3)=0.0
      WIZCW3bQ.0
      BLO(IZOUT3)=0.0
      B(IZOUT3)=0.0
      CC(IZOUT3)=0.0
      JVAR(IZOUT3)=0.0
  190 CONTINUE
CJK
CJK
CJK ************** CARD TYPE 3 ***********************************
CJK
CJK
CJK  IUNIT=UNITS CODE FOR BOARD FEET CORDS, ETC; HARVOL=
CJK  VOLUME HARVEST; PRODPC=PRODUCT SELLING PRICE;
CJK  SYSMHC=SYSTEM MOVE HOURLY COST; DFTBTM=DISTANCE IN MILES
CJK  FROM TRACT BOUNDARY TO MILL
CJK
      READ(KR,200)IUNIT,HARVOL,PRODPC,SYSMHC,DFTBTM
  200 FORMAT(I1,1X,F10.0,1X,F7.2,1X,F7.2,1X,F5.1)
      IF(IUNIT.EQ.1)WRITE(KW,250)HARVOL
  250 FORMAT(2X,'HARVEST VOLUME=',22X,F11.0,2X,'POUNDS')
      IF(IUNIT.EQ.2)WRITE(KW,300)HARVOL
  300 FORMAT(2X,'HARVEST VOLUME=',22X,F11.0,2X,'INT. BOARD FEET')
      IF(IUNIT.EQ.3)WRITE(KW,350)HARVOL
  350 FORMAT(2X,'HARVEST VOLUME=',22X,F11.0,2X,'CUBIC FEET')
      IF(IUNIT.EQ.4)WRITE(KW,360)HARVOL
  360 FORMAT(2X,'HARVEST VOLUME=',22X,F11.0,2X,'CORDS')
      WRITE(KW,400)PRODPC,SYSMHC,DFTBTM
  400 FORMAT(2X,'PRICE IN SELLING UNITS ($)=',15X,F8.2,/,2X,
     1'HOURLY LANDING MOVE COST ($)=',13X,F8.2,/,2X,
     2'DISTANCE FROM WOODS EDGE TO MILL (MILES)=',2X,F6.1)
      WRITE(KW,450)
  450 FORMAT(/,2X,29('*'),/,2X,'DOZER',2X,'DOZER',
     13X,'DOZER',3X,'HOURLY',/,1X,'NUMBER',5X,'HP',3X,'EFFIC',
     25X,'COST',/)
      DO 475 IDL00=1,NMETH
      IF(IUNIT.EQ.1)LOGMET(1,IDL00)=-HARVOL/2000.0
      IF(IUNIT.EQ.2)LOGMET(1,IDL00)=-HARVOL/1000.0
      IF(IUNIT.EQ.3)LOGMET(1,IDL00)=-HARVOL/100.0
      IF(IUNIT.EQ.4)LOGMET(1,IDL00)=-HARVOL/1.0
  475 CONTINUE
      SMDZHC=0.0
```

```
      DO 600 IDL01=1,NDZR
CJK
CJK
CJK *****************CARD TYPE 4   ***********************
CJK
CJK
CJK DZRPH()=DOZER HORSEPOWER; DZREF()=DOZER EFFICEINCY;
CJK DZRHC()=DOZER HOURLY COST; SMDZHC=SDOZER
CJK  HOURLY COST
CJK
      READ(KR,500)DZRHP(IDL01),DZREF(IDL01),DZRHC(IDL01)
  500 FORMAT(F4.0,1X,F4.2,1X,F6.2)
      SMDZHC=SMDZHC+DZRHC(IDL01)
      WRITE(KW,550)IDL01,DZRHP(IDL01),DZREF(IDL01),DZRHC(IDL01)
  550 FORMAT(4X,I3,2X,F5.0,3X,F5.2,2X,F7.2)
  600 CONTINUE
      WRITE(KW,650)SMDZHC
  650 FORMAT(/,2X,29('*'),/,23X,F8.2)
      WRITE(KW,700)
  700 FORMAT(2(/),2X,51('*'),/,46X,'SKIDDER',/,
     12X,'SKIDDER',6X,'SKIDDER',3X,'SKIDDER',2X,
     2'SKIDDER',6X,'HOURLY',/,3X,'NUMBER',3X,
     3'HORSEPOWER',4X,'WEIGHT',4X,'EFFIC',8X,'COST',/)
      SMSKHC=0.0
      DO 850 IDL02=1,NSKD
CJK
CJK
CJK  ************** CARD TYPE 5 **************************
CJK
CJK
CJK  SKDHP()=SKIDDER HORSEPOWER; SKDWT()=SKIDDER WEIGHT;
CJK  SKDEF()=SKIDDER EFFICIENCY; SMSKHC=SUM OF ALL SKIDDERS
CJK  HOURLY COSTS
CJK
      READ(KR,750)SKDHP(IDL02),SKDWT(IDL02),SKDEF(IDL02)
     1,SKDHC(IDL02)
  750 FORMAT(F4.0,1X,F6.0,1X,F4.2,1X,F6.2)
      SMSKHC=SMSKHC+SKDHC(IDL02)
      WRITE(KW,800)IDL02,SKDHP(IDL02),SKDWT(IDL02),SKDEF(IDL02),
     1SKDHC(IDL02)
  800 FORMAT(5X,I5,7X,F6.0,2X,F8.0,1X,F7.2,5X,F7.2)
  850 CONTINUE
      WRITE(KW,900)SMSKHC
  900 FORMAT(/,2X,51('*'),/,45X,F8.2)
      WRITE(KW,950)
  950 FORMAT(2(/),2X,78('*'),/,9X,'** NON-WOODS **',
     13X,'***** WOODS',
     21X,'*****',/,9X,'TRAVEL',3X,'TRAVEL',3X,'TRAVEL',4X,
     3'TRAVEL',3X,'FIXED',/,10X,'EMPTY',3X,'LOADED',4X,'EMPTY',
     44X,'LOADED',4X,'TIME',14X,'CYCLE',4X,'TRUCK',/,2X,
     5'TRUCK',3X,'SPEED',4X,'SPEED',4X,'SPEED',5X,'SPEED',
     65X,'PER',3X,'TRUCK',6X,'TRUCK',3X,'HOURLY',/,1X,
     7'NUMBER',5X,'MPH',6X,'MPH',6X,'MPH',7X,'MPH',4X,'LOAD',
     83X,'EFFIC',5X,'VOLUME',5X,'COST',/)
      SMTKHC=0.0
      DO 1100 IDL03=1,NTRK
CJK
CJK
CJK  ************  CARD TYPE 6  ****************************
CJK
CJK
CJK  TKTENW()=TRUCK TRAVEL SPEED EMPTY OVER NON-WOODS ROAD
CJK  TKTLNW()=TRUCK TRAVEL SPEED LOADED OVER NON-WOODS ROAD
CJK  TKTEWD()=TRUCK TRAVEL SPEED EMPTY OVER WOODS ROAD
CJK  TKTLWD( )=TRUCK TRAVEL SPEED LOADED OVER WOODS ROAD
CJK  TKFTPC()=FIXED TIME PER TRUCK CYCLE IN MINUTES
CJK  TKEF( )=TRUCK EFFICIENCY (IE 0.80)
CJK  TKVOL()=TRUCK VOLUME
CJK  TRAVEL SPEEDS ARE IN MPH
CJK  SMTKHC=SUM OF ALL TRUCKS HOURLY COST
CJK
CJK
      READ(KR,1000)TKTENW(IDL03),TKTLNW(IDL03),TKTEWD(IDL03),
     1TKTLWD(IDL03),TKFTPC(IDL03),TKEF(IDL03),TKVOL(IDL03),
     2TKHC(IDL03)
 1000 FORMAT(5(F4.1,1X),F4.2,1X,F10.2,1X,F6.2)
      SMTKHC=SMTKHC+TKHC(IDL03)
      WRITE(KW,1050)IDL03,TKTENW(IDL03),TKTLNW(IDL03),
     1TKTEWD(IDL03),TKTLWD(IDL03),TKFTPC(IDL03),TKEF(IDL03),
     2TKVOL(IDL03),TKHC(IDL03)
 1050 FORMAT(2X,I4,3X,F6.2,3X,F6.2,3X,F6.2,4X,F6.2,2X,F6.2,2X,
     1F6.2,1X,F10.2,2X,F7.2)
 1100 CONTINUE
      WRITE(KW,1150)SMTKHC
 1150 FORMAT(1(/),2X,78('*'),/,71X,F8.2)
      WRITE(KW,1175)
 1175 FORMAT(1H1,/,2X,26('*'),/,12X,'NUMBER',4X,'NUMBER',/,
     12X,'METHOD',6X,'ROAD',8X,'OF',/,2X,'NUMBER',2X,
     2'SEGMENTS',2X,'LANDINGS',/)
      DO 1250 IDL04=1,NMETH
CJK
CJK
CJK  ************ CARD TYPE 7  ****************************
CJK
CJK
CJK  IMETH=METHOD NUMBER; IRDSEG=NUMBER OF ROAD SEGMENTS
CJK  FOR THIS METHOD; ILAND()= NUMBER OF LANDINGS FOR THIS METHOD
CJK
      READ(KR,1200)IMETH,IRDSEG,ILAND(IDL04)
 1200 FORMAT(I1,1X,I2,1X,I2)
      INRSBM(IDL04)=IRDSEG
      WRITE(KW,1225)IMETH,IRDSEG,ILAND(IDL04)
 1225 FORMAT(4X,I4,6X,I4,6X,I4)
 1250 CONTINUE
      WRITE(KW,1275)
 1275 FORMAT(/,2X,26('*'),//)
      WRITE(KW,1300)
 1300 FORMAT(2(/),2X,43('*'),/,22X,'NUMBER',/,
     12X,'METHOD',3X,'LANDING',2X,6X,'OF',5X,'MAXIMUM AREA',/,
     22X,'NUMBER',4X,'NUMBER',5X,'AREAS',5X,'CODE  NUMBER',/)
 1325 CONTINUE
CJK
CJK    ******************  CARD TYPE 8  ********************
CJK
CJK
CJK    JMN=METHOD NUMBER; JLN=LANDING NUMBER;
CJK    JNA= NUMBER OF AREAS
CJK    JMAN=MAXIMUM VALUE OF AREA CODE NUMBER ; IS THE SAME
CJK    AS JNA ONLY IF AREAS ARE CODED IN NUMERICAL SEQUENCE
CJK
CJK
CJK
      READ(KR,1350)JMN,JLN,JNA,JMAN
 1350 FORMAT(I1,1X,I2,1X,I2,1X,I2)
      IF(JMN.EQ.0)GO TO 1400
      JNAREA(JMN,JLN)=JMAN
      WRITE(KW,1375)JMN,JLN,JNA,JMAN
 1375 FORMAT(4X,I4,6X,I4,6X,I4,14X,I3)
      GO TO 1325
 1400 WRITE(KW,1425)
 1425 FORMAT(/,2X,43('*'),2(/))
      WRITE(KW,1450)
 1450 FORMAT(2(/),2X,127('*'),/,59X,'CUT',3X,'FILL',4X,'ROAD',
     1/,2X,'METHOD',2X,'SEGMENT',3X,'DOZER',5X,'ROAD',3X,
     2'ROAD',3X,'ROAD',3X,'SIDE',2X,'SLOPE',2X,'SLOPE',4X,'TYPE',
     34X,'CUBIC',
     44X,'ACRES',2X,'SEGMENT',2X,'SEGMENT',2X,'METHOD',2X,
     5'METHOD',/,2X,'NUMBER',3X,'NUMBER',2X,'NUMBER',3X,
     6'LENGTH',2X,'WIDTH',2X,'SLOPE',2X,'SLOPE',2X,'RATIO',2X,
     7'RATIO',4X,'CODE',4X,'YARDS',2X,'CLEARED',4X,'HOURS',
     85X,'COST',3X,'HOURS',4X,'COST',/)
CJK
CJK
CJK      START OF DO LOOP BY METHOD++++ROAD CONSTRUCTION TIMES
CJK
CJK
      DO 1850 IDL05=1,NMETH
      SMRDSL=0.0
      SMRDCY=0.0
      SMRDNA=0.0
      SMRDHR=0.0
      SMRDHM=0.0
      IDLB01=INRSBM(IDL05)
      IDLB02=INRSBM(IDL05)
      IF(IDLB01.EQ.0)IDLB02=1
CJK
CJK
CJK      START OF DO LOOP BY ROAD SEGMENT+++ROAD CONSTRUCTION TIMES
CJK
CJK
      DO 1650 IDL06=1,IDLB02
CJK
CJK
CJK ************** CARD TYPE 10  **************************
CJK
CJK
CJK   ROADSL=ROAD SEGMENT LENGTH IN FEET; ROADSW=ROAD
CJK   SEGMENT WIDTH ISEGMENT SLOPE IN PERCENT
CJK   OF DIRECTION BUILT; ROADSS=ROAD SEGMENT SIDE SLOPE IN
CJK   IN PERCENT; ROADCR=ROAD SEGMENT CUT RATI; ROADFR=
CJK   ROAD SEGMENT FILL RATIO; ROADTY=ROAD DIFFICULTY CODE
CJK
CJK
CJK
      READ(KR,1500)ROADSL,ROADSW,ROADSP,ROADSS,ROADCR,ROADFR,ROADTY
 1500 FORMAT(F7.0,1X,F4.1,1X,F5.0,1X,F5.0,1X,F5.2,1X,F5.2,1X,F5.0)
      IF(IDLB01.EQ.0)GO TO 1700
      IF(ROADSL.EQ.0.0)GO TO 1700
CJK FOLLOWING EQUATIONS COMPUTE CUBIC YARDS OF EARTH REMOVED
CJK IN ROAD BUILDING BASED ON EQUATIONS BY JOHN K. BOWMAN,
CJK ROBERT B. MCCREA, AND CARL L. FONNESBECK "A METHOD
CJK OF FIELDDESIGN APPLIED TO FOREST ROADS" PAGE 194,
CJK IN: LOW VOLUME ROADS, SPECIAL REPORT 160, TRANSPORTATION
CJK RESEARCH BORAD, NATIONAL RESEARCH COUNCIL, NATIONAL
CJK ACADEMY OF SCIENCES, WASHINGTON DC, 1975
CJK
CJK
CJK
CJK    SHRIKF HAS A VALUE OF 0.20 IN ORDER TO OBTAIN THE VALUES
CJK    FOR CUBIC YARDS AND ACRES GIVEN IN THE 4 TH EDITION OF
CJK    "ENGINEERING FIELD TABLES" USDA FOREST SERVICE AND BLM
CJK    JULY 1976,  (EM7100-10)
CJK
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```
      CJK
            SHRIKF=0.20
            ROADSD = ATAN(ROADSS/100.0)*CTDEG
            ROADCS = ATAN(ROADCR)*CTDEG
            ROADSF=1.000-(0.014*ROADSP)-(0.00019*ROADSP*ROADSP)
            ROADFS = ATAN(ROADFR)*CTDEG
            cm = COTAN(ROADSD*CTRAD)
            A1 = COTAN(ROADSD*CTRAD)-ROADCR
            i i = A1*(1+SHRIKF)
            A? = COTAN(ROADSD*CTRAD)-ROADFR
            A3 = SQRT(A1/A2)
            A4 = ROADSW/2.0*(A3-1.0)
            BK = A4/(A3+1.0)
            DF = ((ROADSW/2.0)-BK)/(COTAN(ROADSD*CTRAD)-ROADFR)
            DC = (BK+ROADSW/2.0)/(COTAN(ROADSD*CTRAD)-ROADCR)
            THETA = 180.0-ROADCS
            BASE1 = DC/TAN(ROADSD*CTRAD)
            THETA = 180.0-ROADFS
            AREAF = (1.0/2.0)*(ROADSW/2.0)*ROADFR*SIN(THETA*CTRAD)
            BASE2 = DF/TAN(ROADSD*CTRAD)
            BASE = BASE1+BASE2
            BASECU=DC/TAN(ROADCS*CTRAD)
            AREAC=(0.5*((ROADSW/2.0)+BK+BASECU)*DC)-(0.5*BASECU*DC)
            ROADNA = (BASE*1000.0)/43560.0
            ROADCY = (AREAC*1000.0)/27.0
            CUBEYD=(AREAC*ROADSL)/27.0
            ACRES=(BASE*ROADSL)/43560.0
            SMRDSL=SMRDSL+ROADSL
            SMRDCY=SMRDCY+CUBEYD
            SMRDNA=SMRDNA+ACRES
            SMRDSH=0.0
      CJK
      CJK
      CJK    START OF DO LOOP FOR DOZERS++++ROAD CONSTRUCTION TIMES
      CJK
      CJK
            DO 1600 IDL07=1,NDZR
      CJK
      CJK   SEGRDH=HOURS m BUILD THIS ROAD SEGMENT; BASED ON EQUATION
      CJK   BY JERRY KOGER "FACTORS AFFECTING THE CONSTRUCTION AND
      CJK   COST OF LOGGING ROADS" TVA TECHNICAL NOTE B27, TENNESSEE
      CJK   VALLEY AUTHORITY, NORRIS, TN, 37828 PAGE 30, 1978
      CJK   EQUATION MODIFIED BY LATER ANALYSIS INTO DIFFERENT ROAD
      CJK   TYPES... SEE FACTOR ROADTY FOR THIS ADJUSTMENT
      CJK   ROADCY= CUBIC YARDS OF EARTH PER 1000 FT OF ROAD;
      CJK   ROADNA= NUMBER OF ACRES OF CLEARED RIGHT OF WAY PER
      CJK   100SLOPE CORRECTION FACTOR m
      CJK   PRODUCE VALUES GIKN IN FIGURE 22 OF TVA TECH NOTE B27
      CJK
      CJK
            SEGRDH=(ROADSL/ROADTY)*
           1(0.524*SQRT(ROADCY/(ROADSF*DZRHP(IDL07)))+
           212.668*SQRT(ROADNA/(ROADSF*DZRHP(IDL07))))/DZREF(IDL07)
            SMRDSH=SMRDSH+(1.0/SEGRDH)
            SEGRDC=SEGRDH*DZRHC(IDL07)
            WRITE(KW,1550)IDL05,IDL06,IDL07,ROADSL,ROADSW,ROADSP,
      [illegible]
      1550 FORMAT(4X,I4,5X,I4,4X,I4,1X,F6.0,1X,F8.1 ... [illegible] 1X
           1F6.0,2X,F5.2,2X,F5.2,2X,F6.0,1X,F8.1,1X,F8.1,1X,F8.1,F9.2)
      1600 CONTINUE
      CJK
      CJK
      CJK   SMRDHS=NUMBER OF HOURS TO BUILD THIS ROAD SEGMENT
      CJK   IF ALL DOZERS WORKED TOGETHER
      CJK
      CJK
            SMRDHS=1.0/SMRDSH
            SMRDHM=SMRDHM+SMRDHS
            SMRDCS=SMRDHS*SMDZHC
            SMRDCM=SMRDHM*SMDZHC
            IF(NDZR.GT.1)WRITE(KW,1625)IDL05,IDL06,SMRDHS,SMRDCS
      1625 FORMAT(4X,I4,5X,I4,81X,F6.1,F9.2)
      1650 CONTINUE
      1700 CONTINUE
            IF(IDLB01.EQ.0)SMRDHM=0.0
            IF(IDLB01.EQ.0)SMRDCM=0.0
            LOGMET(2,IDL05)=SMRDHM
            WRITE(KW,1800)IDL05,SMRDSL,SMRDCY,SMRDNA,
           1SMRDHM,SMRDCM
      1800 FORMAT(4X,I4,17X,F9.0,43X,F9.1,1X,F8.1,18X,F8.1,F8.0//)
      1850 CONTINUE
            WRITE(KW,1900)
      1900 FORMAT(/,127('*'))
            WRITE(KW,1950)
      1950 FORMAT(1H1,//,2X,127('*'),/,110X,'WEIGHTED',5X,'METHOD',/,
           119X,'DISTANCE',3X,'LANDING',2X,'AVERAGE',10X,'HOURLY',
           211X,'LANDING',3X,'LANDING',3X,'SYSTEM',3X,'SYSTEM',
           32X,'BUILDING',5X,'MOVE &',/,2X,'METHOD',2X,'LANDING',6X,
           4'FROM',6X,'SIZE',6X,'CUT',3X,'DOZER',3X,'DOZER',3X,'EFFIC',
           52X,'BUILDING',2X,'BUILDING',5X,'MOVE',5X,'MOVE',2X,
           6'& MOVING',4X,'LANDING',
           6/,2X,'NUMBER',3X,'NUMBER',2X,'BOUNDARY',5X,
           7'ACRES',4X,'DEPTH',6X,'HP',4X,'COST',4X,'CODE',5X,
           8'HOURS',6X,'COST',4X,'HOURS',5X,'COST',5X,'HOURS',
           97X,'COST',/)
      CJK
      CJK
      CJK   *********** CARD TYPE 11 *****************************
      CJK
      CJK
      CJK   ILDZR=INPUT ORDER NUMBER OF DOZER USED m BUILD
      CJK    LANDINGS... ONLY ONE DOZER IS ALLOWED m WILD
      CJK   LANDINGS
      CJK
      CJK
      CJK
            READ(KR,2000)ILDZR
      2000 FORMAT(I1)
      CJK
      CJK
      CJK      START OF DO LOOP FOR METHODS++++ LANDING CONSTRUCTION TIMES
      CJK
      CJK
            DO 2200 IDL08=1,NMETH
            SMHRLA=0.0
            SMCBL=0.0
            SMSYMH=0.0
            SMCML=0.0
            IDLB03=ILAND(IDL08)
      CJK
      CJK
      CJK     START OF CO LOOP FOR LANDINGS+++++LANDING CONSTRUCTION TIMes
      CJK
      CJK
            al 2150 IDL09=1,IDLB03
      CJK
      CJK
      CJK   ************* CARD TYPE 12 ************************
      CJK
      CJK
      CJK   DSFTB()=DISTANCE IN FEET FROM TRACT BOUNDARY m MIS LANDIG
      CJK   ACRESL= ACRES IN THIS LANDING... SIZE OF LANDING
      CJK   CUTL=AVERAGE CUT DEPTH OF EARTH REMOVED IN BUILDING LANDING
      CJK   EFFL=DEFFICIENCY FACTOR FOR THIS LANDING (IE 0.80)
      CJK   SYSMHR=SYSTEM MOVE TIME IN HOURS m THIS LANDING; NOT A
      CJK   MOVE IN TIM BUT A MOVE BETWEEN LANDING TIME
      CJK
      CJK
            READ(KR,2050)DSFTB(IDL08,IDL09),ACRESL,CUTL,EFFL,SYSMHR
      2050 FORMAT(F8.0,1X,F4.1,1X,F4.1,1X,F4.2,1X,F5.1)
            APPLL=(ACRESL*43560.0)/26.70
            APPCYL=((APPLL*CUTL*26.70)/27.0)/(APPLL/1000.0)
            APPACL=(((APPLL*26.70)/43560.0))/(APPLL/1000.0)
      CJK
      CJK    LOGIC WAS m CONVERT LANDING SIZIN ACRES m AN
      CJK    EQUIVALENT LENGHT OF ROAD AND THEN USE ROAD
      CJK    CONSTRUCTION EQUATION IN TVA TECH NOTE B27
      CJK    APPCYL=APPROXIMATE NUMBER OF CUBIC YARDS
      CJK    APPACL=APPROXIMATED NUMBER CF ACRES IF CONVERTED
      CJK           FROM LANDING ACRES TO ROAD LENGTH ACRES
      CJK    HRTBL=HOURS m BUILD LANDING
      CJK
      CJK
            HRTBL=(APPLL/3000.0)*(0.524*SQRT(APPCYL/DZRHP(ILDZR))+
           1(12.668*SQRT(APPACL/DZRHP(ILDZR))))/(DZREF(ILDZR)*EFFL)
            SMHRLA=SMHRLA+HRTBL
            CBL=HRTBL*DZRHC(ILDZR)
            SMCBL=SMCBL+CBL
            CML=SYSMHR*SYSMHC
            SMCML=SMCML+CML
            SMSYMH=SMSYMH+SMCML
            WRITE(KW,2100)IDL08,IDL09,DSFTB(IDL08,IDL09),ACRESL,CUTL,
           1DZRHP(ILDZR),DZRHC(ILDZR),EFFL,HRTBL,CBL,SYSMHR,CML
      2100 FORMAT(4X,I4,5X,I4,1X,F9.0,4X,F6.1,3X,F6.1,2X,F6.0,
           11X,F7.2,2X,F6.2,1X,F9.2,1X,F9.2,2X,F7.1,1X,F8.2)
      2150 CONTINUE
            WLBH1=DZRHC(ILDZR)+SYSMHC
            WLBHRS=(SMCBL+SMCML)/WLBH1
      CJK
      CJK
      CJK   WLBHRS=WEIGHTED HOURS FOR BUILDING LANDING AND
      CJK   MOVING BETWEEN LANDINGS ** MIS VALUE IS USED
      CJK   IN THE LP HOURS COLUMNS BY METHOD
      CJK
      CJK
            SMCLMM=SMCBL+SMCML
            WRITE(KW,2175)IDL08,WLBHRS,SMCLMM
      2175 FORMAT(4X,I4,103X,F8.2,2X,F9.2)
            LOGMET(3,IDL08)=WLBHRS
      2200 CONTINUE
            WRITE(KW,2250)
      2250 FORMAT(/,2X,127('*'),//)
            WRITE(KW,2300)
      2300 FORMAT(2(/),1X,127('*'),/,49X,'MINIMUM',4X,'MAXIMUM',6X,
           1'FIXED',
           24X,'SKIDDING',3X,'TRAIL',3X,'SLOPE',9X,'AREA',2X,'FIXED',/,
           32X,'METHOD',2X,'LANDING',4X,'AREA',7X,'AREA',5X,'AREA',
           43X,'SKIDDING',3X,'SKIDDING',3X,'SKIDDING',2X,'CORRECTION',
           53X,'TRAVEL LOADED',3X,'DIFFICULTY',2X,'TIME',/,
           62X,'NUMBER',3X,'NUMBER',2X,'NUMBER',5X,'VOLUME',4X,
           7'ACRES',3X,'DISTANCE',3X,'DISTANCE',3X,'DISTANCE',6X,
           8'FACTOR',3X,'DIRECTION (%)',7X,'FACTOR',2X,'CYCLE',/)
      2350 CONTINUE
      CJK
      CJK
```

```
CJK ************CARD TYPE 13 ***********************************
CJK
CJK
CJK   IMN=METHOD NUMBER, ILN=LANDING NUMBER,IAN=AREA NUMBER,
CJK   AV=AREA VOLUME, AA=AREA ACRES, AN=MINIMUM SKIDDING
CJK   DISTANCE, AX=MAXIMUM SKIDDING DISTANCE, AF=FIXED SKIDDING
CJK   TO AREA WHERE AN AND Ax WOULD APPLY; AC=CORRECTION FACTOR
CJK   CONVERTING STRAIGHT LINE SKIDDING DISTANCE TO ACTUAL
CJK   DISTANCE TRAVELED BY SKIDDER; AS=SLOPE OF SKID TRAIL IN
CJK   PERCENT IN DIRECTION OF TRAVEL LOADED; AD=AREA DIFFICULTY
CJK   CODE AFFECTING SKIDDING TIME SIMILAR TO SKIDDER EFFICIENCY
CJK (IE 0.80)
CJK
CJK
 2375 CONTINUE
      READ(KR,2400)IMN,ILN,IAN,AV,AA,AN,AX,AF,AC,AS,AD,AT
 2400 FORMAT(I1,I2,I2,F9.0,F6.0,F8.0,
     1F8.0,F8.0,1X,F5.2,F5.0,1X,F4.2,1X,F4.1)
      IF(IMN.EQ.0)GO TO 2500
      AREAV(IMN,ILN,IAN)=AV
      AREAA(IMN,ILN,IAN)=AA
      AREAMN(IMN,ILN,IAN)=AN
      AREAMX(IMN,ILN,IAN)=AX
      AREAFD(IMN,ILN,IAN)=AF
      AREACF(IMN.ILN.IAN)=AC
      AREATS(IMN,ILN,IAN)=AS
      AREADI(IMN,ILN,IAN)=AD
      AREAFT(IMN.ILN.IAN)=AT
      WRITE(KW,2450)IMN,ILN,IAN,AV,AA,AN,AX,AF,AC,AS,AD,AT
 2450 FORMAT(4X.I4.5X.I4.4X.I4.1X.F10.0,2X,F7.0,2X,F9.0,
     12X,F9.0,2X,F9.0,5X,F7.2,10X,F6.0,6X,F7.2,1X,F6.1)
      GO TO 2350
 2500 CONTINUE
      WRITE(KW.2250)
      WRITE(KW,2550)
 2550 FORMAT(1H1,/,2X,126('*'),/,75X,11('*'),1X,'ALL'
     1,1X,'SKIDDERS WORKING TOGETHER',1X,11('*'),/,68X,
     2'AREA',/,28X,'MINIMUM',3X,'MAXIMUM',4X,'CYCLE',2X,
     3'NUMBER',6X,'SKID',10X,'AREA',4X,'LANDING ',2X,
     4'LANDING',5X,'METHOD',6X,'METHOD',/,2X,
     5'METHOD',2X,'LAND',2X,'AREA',2X,'SKID',3X,'VOLUME',
     64X,'VOLUME',5X,'TIME',6X,'OF',6X,'TIME',6X,
     7'SKIDDING',3X,'SKIDDING'.2X.'SKIDDING',3X.'SKIDDING',
     84X,'SKIDDING')
      WRITE(KW,2600)
 2600 FORMAT(6X.'NO',4X.'NO',4X.'NO',4X,'NO',2X,
     1'SKIDDED',3X,'SKIDDED',2X,'MINUTES',2X,'CYCLES',
     25X,'HOURS',9X,'HOURS',7X,'HOURS',5X,'COSTS',6X,
     3'HOURS',7X,'COSTS',/)
CJK
CJK
CJK       START OF DO LOOP FOR METHODS++++SKIDDING TIMES
CJK
CJK
CJK   SKIDDING AVERAGE VALUES FROM TVA TECHNICAL NOTE B18, 1976
CJK   BY JERRY KOGER "FACTORS AFFECTING THE PRODUCTION OF
CJK   RUBBER TIRED SKIDDERS" TVA, NORRIS, TN 37828
CJK   RADCUR = RADIUS OF CURVATURE AVERAGE VALUE CF 483.99 FT
CJK   RUTD=RUTD DEPTH ON SKID TRAIL; VALUE OF 2" ASSUMED
CJK   CONEP= SOIL STRENGTH BY CONE PENETROMETER, ASSUMED 200
CJK   ARCLG= ARC LENGTH OF SKID TRAIL, USED AVERAGE OF 132.
CJK   SEE NA TECHNOTE B18 PAGE 23 FCR THESE VALUES
CJK
      RADCUR=483.99
      RUTD=6.3
      CONEP=192.2
      ARCLG=131.6
      ELEV=1547.1
      DO 3100 IDL10=1,NMETH
      SMVOLM=0.0
      SMACLM=0.0
      SMHMA=0.0
      SASKD=0.0
      SFSKD=0.0
      SWSKD=0.0
      IDLB04=ILAND(IDL10)
CJK
CJK
CJK       START OF m LOOP FOR LANDINGS++++++ SKIDDING TIMES
CJK
CJK
      DO 3000 IDL11=1,IDLB04
      SMHLA=0.0
      SMAA=0.0
      SMAV=0.0
      ASKDPL=0.0
      FSKDPL=0.0
      WSKDPL=0.0
      AMAXN=0.0
      IDLB05=JNAREA(IDL10,IDL11)
CJK
CJK
CJK      START OF DO LOOP FOR AREA+++++SKIDDING TIMES
CJK
CJK
      DO 2900 IDL12=1,IDLB05
      IF(AREAV(IDL10,IDL11,IDL12).EQ.0.0)GO m 2900
      SMHA=0.0
      AMAXN=AMAXN+1.0
      SMAV=SMAV+AREAV(IDL10,IDL11,IDL12)
      SMAA=SMAA+AREAA(IDL10,IDL11,IDL12)
      ASKDPL=ASKDPL+0.5*(AREAMN(IDL10,IDL11,IDL12)+
     1AREAMX(IDL10,IDL11,IDL12))
      FSKDPL=FSKDPL+AREAFD(IDL10,IDL11,IDL12)
      WSKDPL=WSKDPL+(((0.5*(AREAMN(IDL10,IDL11,IDL12)+
     1AREAMX(IDL10,IDL11,IDL12)))*AREACF(IDL10,IDL11,IDL12))+
     2AREAFD(IDL10,IDL11,IDL12))*AREAV(IDL10,IDL11,IDL12)
CJK
CJK
CJK    START OF DO LOOP FOR SKIDDERS++++SKIDDING TIMES
CJK
CJK
      DO 2800 IDL13=1,NSKD
CJK
CJK
CJK   ************** CARD TYPE 15 ****************************
CJK
CJK
CJK   KM=MEHTOD NUMBER; KL=LANDING NUMBER;KA=AREA NUMBER;
CJK   KS=SKIDDER NUMBER; SKVMN=MINIMUM VOLUME SKIDDED PER CYCLE;
CJK   SKVMS=MAXIMUM VOLUME SKIDDED PER CYCLE;
CJK   IF SKVMN=SKVMX THEN INTEGRATION
CJK   EQUATION FOR SKIDDING TIME IS NOT USED
CJK
CJK
CJK
      READ(KR,2700)KM,KL,KA,KS,SKVMN,SKVMX
 2700 FORMAT(I1,1X,I2,1X,I2,1X,I2,F10.1,F10.1)
      XN=AREAMN(KM,KL,KA)
      XX=AREAMX(KM,KL,KA)
      FX=AREAFD(KM,KL,KA)
      FC=AREACF(KM,KL,KA)
CJK
CJK
CJK    CODE SYMBOLS USED FAC=FACTOR; A...=SYMBOL IN APPENDIX
CJK     OF THIS REPORT FOR SKIDDING EQUATION; E=SYMBOL FOR
CJK    TRAVEL EMPTY .........THIS APPLIES TO FACAE,FACBE
CJK    TYPE CODEING USED BELOW
CJK
CJK
      IF(XN.EQ.XX)FACAE=(FX+(XN*FC))**1.022449
CJK
CJK
CJK    IF XN.NE.XX THEN INTEGRATION EQUATION IS USED TO COMPUTE
CJK    VALUE OF FACAE ++TRAVEL EMPTY
CJK
CJK
      IF(XN.NE.XX)FACAE=(FX**1.022449)+((1.0/(XX*FC-XN*FC))*
     1(((XX*FC)**2.022449/2.022449)-((XN*FC)**2.022449/2.022449)))
      FACBE=RADCUR**3.549048
      FACCE=(SKDHP(IDL13))**1.317563
      FACCE=120.0**1.317563
      FACDE=(1.0+RUTD)**0.223969
CJK   FACEE=(AREAE(KM,KL,KA))**0.180727
      FACEE=ELEV**0.180727
      TS=ATAN(AREATS(KM,KL,KA)/100.0)*CTDEG
      FACFE=(1.0+SIN(TS*CTRAD))**2.156775
      FACHE=CONEP**0.183381
      FACIE=ARCLG**6.943695
      IF(IUNIT.EQ.1)VSN=SKVMN*CONPTB
      IF(IUNIT.EQ.1)VSX=SKVMX*CONPTB
      IF(IUNIT.EQ.2)VSN=SKVMN*CONBTB
      IF(IUNIT.EQ.2)VSX=SKVMX*CONBTB
      IF(IUNIT.EQ.3)VSN=SKVMN*CONCTB
      IF(IUNIT.EQ.3)VSX=SKVMX*CONCTB
      IF(IUNIT.EQ.4)VSN=SKVMN*CONUTB
      IF(IUNIT.EQ.4)VSX=SKVMX*CONUTB
      IF(SKVMN.EQ.SKVMX)FACJL=VSN**0.110305
CJK
CJK
CJK    IF SKVMN.NE.SKVMX THEN INTEGRATION EQUATION IS USED
CJK    TO COMPUTE VALUE OF FACJL  *** VOLUME FACTOR FOR
CJK    TRAVEL LOADED
CJK
CJK
      IF(SKVMN.NE.SKVMX)FACJL=((1.0/(VSX-VSN))*
     1((VSX**1.110305)/1.110305)*
     2((VSN**1.110305)/1.110305))
      IF(XN.EQ.XX)FACAL=(FX+(XN*FC))**1.1098034
CJK
CJK
CJK    IF XN.NE.XX THEN INTEGRATION EQUATION IS USED TO COMPUTE
CJK    VALUE OF FACAL+++ DISTANCE FACTOR--TRAVEL LOADED
CJK
CJK
      IF(XN.NE.XX)FACAL=(FX**1.1098034)+((1.0/(XX*FC-XN*FC))*
     1(((XX*FC)**2.1098034/2.1098034)-((XN*FC)**2.1098034
     2/2.1098034)))
      FACBL=RADCUR**3.472234
      FACDL=(1.0+RUTD)**0.116935
C     FACEL=(AREAE(KM,KL,KA))**0.098604
      FACEL=ELEV**0.098604
      FACFL=(1.0+SIN(TS*CTRAD))**0.681159
      FACGL=(SKDWT(IDL13))**3.234567
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```
      FACHL=CONEP**0.067053
      FACCL=(SKDHP(IDL13))**3.157504
      FACIL=AROLG**7.456998
      TIMEE=0.3395469*((FACAE*FACBE*FACCE*FACDE*FACEE*FACFE)/
     1(FACHE*FACIE))
      TIMEL=0.00005166*((FACJL*FACAL*FACBL*FACDL*FACEL*
     1FACFL*FACGL)/(FACHL*FACCL*FACIL))
CJK
CJK
CJK T=SKIDDING CYCLE TIME IN MINUTES AS COMPUTED BY EQUATION
CJK  2 PAGE 31 OF TVA TECHNICAL NOTE B18, 1976 BY JERRY KOGER
CJK  "FACTORS AFFECTING THE PRODUCTION OF RUBBER TIRED SKIDDERS"
CJK  TVA, NORRIS, TN, 37828
CJK
CJK  TIMEE=TRAVEL TIK EMPTY; TIMEL=TRAVEL TIME LOADED;
CJK  AREAFT()=FIXED CYCLE TIME; SKEF=SKIDDER EFFICIENCY;
CJK AREADI(,) =AREA DIFFICULTY FACTOR FOR SKIDDING
CJK
CJK
      T=((TIMEE+TIMEL+AREAFT(KM,KL,KA))/SKDEF(KS))/AREADI(KM,KL,KA)
      SKSFE=(FACBE*FACCE*FACDE*FACEE)/(FACHE*FACIE)
      SKSFL=(FACBL*FACDL*FACEL)/(FACHL*FACIL)
      CYCLEN=(AREAV(KM,KL,KA))/((SKVMN+SKVMX)/2.0)
      ATH=(T*CYCLEN)/60.0
      WRITE(KW,2750)KM,KL,KA,KS,SKVMN,SKVMX,T,CYCLEN,ATH
 2750 FORMAT(4X,I4,2X,I4,2X,I4,2X,I4,2X,I4,F9.1,1X,F9.1,1X,
     1F8.2,1X,F7.0,F10.2)
      SMHA=SMHA+(1.0/ATH)
 2800 CONTINUE
CJK
CJK
CJK  SMHAA= THE TIME IT WOULD TAKE ALL SKIDDERS IF MEY
CJK  WORKED TOGETHER ON THIS AREA
CJK
CJK
      SMHAA=1.0/SMHA
      SMHLA=SMHLA+SMHAA
      IF(NSKD.GT.1)WRITE(KW,2850)KM,KL,KA,SMHAA
 2850 FORMAT(4X,I4,2X,I4,2X,I4,57X,F10.2)
 2900 CONTINUE
      VOLML(IDL10,IDL11)=SMAV
      VOLMA(IDL10,IDL11)=SMAA
      ASKDBL(IDL10,IDL11)=ASKDPL/AMAXN
      FSKDBL(IDL10,IDL11)=FSKDPL/AMAXN
      SWSKD=SWSKD+WSKDPL
      WSKDBL(IDL10,IDL11)=WSKDPL/SMAV
      SASKD=SASKD+ASKDBL(IDL10,IDL11)
      SFSKD=SFSKD+FSKDBL(IDL10,IDL11)
      SMHMA=SMHMA+SMHLA
      SKDLC=SMHLA*SMSKHC
      SMVOLM=SMVOLM+SMAV
      SMACLM=SMACLM+SMAA
      WRITE(KW,2950)KM,KL,SMHLA,SKDLC
 2950 FORMAT(4X,I4,2X,I4,73X,F10.2,F10.2)
 3000 CONTINUE
      VOLBM(IDL10)=SMVOLM
      ACRBM(IDL10)=SMACLM
      SKDMC=SMHMA*SMSKHC
      LOGMET(4,IDL10)=SMHMA
      ADL11=IDLB04
      ASKDBM(IDL10)=SASKD/ADL11
      FSKDBM(IDL10)=SFSKD/ADL11
      WSKDBM(IDL10)=SWSKD/SMVOLM
      WRITE(KW,3050)KM,SMHMA,SKDMC
 3050 FORMAT(4X,I4,99X,F11.2,1X,F11.2,//)
 3100 CONTINUE
      WRITE(KW,3125)
 3125 FORMAT(/,2X,126('*'))
      WRITE(KW,3150)
 3150 FORMAT(1H1,2(/),125('*'),/,62X,8('*'),' PER LANDING',1X,
     19('*'),5X,9('*'),' PER METHOD',1X,9('*'),/,
     284X,'WEIGHTED',27X,'WEIGHTED',/,74X,'AVERAGE',4X,'AVERAGE',
     317X,'AVERAGE ',3X,'AVERAGE',/,63X,'AVERAGE',6X,'FIXED',5X,
     4'TRAVEL',6X,'AVERAGE',6X,'FIXED',5X,'TRAVEL',/,2X,
     5'METHOD',2X,'LANDING',3X,'LANDING',3X,'LANDING',5X,
     6'METHOD',5X,'METHOD',3X,'SKIDDING',3X,'SKIDDING',3X,
     7'SKIDDING',5X,'SKIDDING',3X,'SKIDDING',3X,'SKIDDING',/,
     82X,'NUMBER',3X,'NUMBER',4X,'VOLUME',5X,'ACRES',5X,'VOLUME',
     96X,'ACRES',3X,'DISTANCE',3X,'DISTANCE',3X,'DISTANCE',
     15X,'DISTANCE',3X,'DISTANCE',3X,'DISTANCE',/)
      DO 3250 IDL14=1,NMETH
      IDLB5A=ILAND(IDL14)
      DO 3230 IDL14A=1,IDLB5A
CJK
CJK
CJK  OUTPUT LANDING AND METHOD VOLUMES AND SKIDDING INFO
CJK  BY LANDING ONLY
CJK
CJK
      WRITE(KW,3220)IDL14,IDL14A,VOLML(IDL14,IDL14A),
     1VOLMA(IDL14,IDL14A),ASKDBL(IDL14,IDL14A),
     2FSKDBL(IDL14,IDL14A),WSKDBL(IDL14,IDL14A)
 3220 FORMAT(4X,I4,5X,I4,1X,F9.0,2X,F8.0,25X,F8.0,3X,F8.0,3X,F8.0)
 3230 CONTINUE
CJK
CJK
CJK OUTPUT LANDING AND METHOD VOLUME, ACRES AND SKIDDING
CJK  DISTANCES BY METHOD ONLY
CJK
CJK
      WRITE(KW,3240)IDL14,VOLBM(IDL14),ACRBM(IDL14),
     1ASKDBM(IDL14),FSKDBM(IDL14),WSKDBM(IDL14)
 3240 FORMAT(4X,I4,30X,F10.0,1X,F10.0,37X,F9.0,2X,F9.0,2X,F9.0)
 3250 CONTINUE
      WRITE(KW,3300)
 3300 FORMAT(/,2X,125('*'))
      WRITE(KW,3350)
 3350 FORMAT(2(/),2X,27('*'),/,24X,'TRUCK',/,
     123X,'TRAVEL',/,2X,'METHOD',2X,'LANDING',2X,
     2'CORRECTION',/,2X,'NUMBER',3X,'NUMBER',6X,'FACTOR',/)
      DO 3500 IDL15=1,NMETH
      IDLB06=ILAND(IDL15)
      DO 3400 IDL16=1,IDLB06
CJK
CJK ************** CARD TYPE 16 **********************
CJK
CJK
CJK   ITMN=METHOD NUMBER; ITLN=LANDING NUMBER FOR MIS METHOD
CJK   TKTVCF=TRUCK SPEED CORRECTION FACTOR THAT RECOGNIZES
CJK   THAT TRAVEL SPEED MAY DECREASE AS THE ROAD STANDARD
CJK   DECREASES AS A FUNCTION OF ROAD LENGTH
CJK   (IE 0.80 WOULD MEAN THAT TRAVEL SPEED AT THE EN,
CJK   WAS 80 % OF BEGINNIG TRAVEL SPEED)
CJK
CJK
      READ(KR,3360)ITMN,ITLN,TKTVCF
 3360 FORMAT(I1,1X,I2,1X,F4.2)
      TKTCF(IDL15,IDL16)=TKTVCF
      WRITE(KW,3370)ITMN,ITLN,TKTVCF
 3370 FORMAT(4X,I4,5X,I4,6X,F6.2)
 3400 CONTINUE
 3500 CONTINUE
      WRITE(KW,3550)
 3550 FORMAT(/,2X,27('*'),//)
      WRITE(KW,3600)
 3600 FORMAT(1H1,/,2X,94('*'),/,57X,5('*'),1X,'ALL TRUCKS',1X,
     1'WORKING TOGETHER',1X,5('*'),/,
     228X,'CYCLE',4X,'NUMBER',5X,'TRUCK',5X,'LANDING',
     33X,'LANDING',5X,'METHOD',5X,'METHOD'/,
     42X,'METHOD',2X,'LANDING',3X,'TRUCK',4X,'TIME',8X,
     5'OF',6X,'TIME',4X,'TRUCKING',2X,'TRUCKING',3X,
     6'TRUCKING',3X,'TRUCKING',/,
     72X,'NUMBER',3X,'NUMBER',2X,'NUMBER',3X,'HOURS',5X,
     8'LOADS',5X,'HOURS',7X,'HOURS',6X,'COST',
     96X,'HOURS',7X,'COST',/)
CJK
CJK
CJK  START OF DO  LOOP FOR METHODS++++TRUCKING TIMES
CJK
CJK
      DO 3950 IDL16=1,NMETH
      SMTKMH=0.0
      IDLB07=ILAND(IDL16)
CJK
CJK
CJK  START OF  DO LOOP FOR LANDINGS++++TRUCKING TIMES
CJK
CJK
      DO 3850 IDL17=1,IDLB07
      SMTKLH=0.0
      SMTKH=0.0
      DO 3750 IDL18=1,NTRK
CJK
CJK
CJK  START OF DO LOOP FOR TRUCKS+++TRUCKING TIMES
CJK
CJK
      TKTEWM=DFTBTM/TKTENW(IDL18)
      TKTLWM=DFTBTM/TKTLNW(IDL18)
      TKTEBR=(DSFTB(IDL16,IDL17)/5280.0)/
     1((TKTEWD(IDL18)*(1.0+TKTCF(IDL16,IDL17)))/2.0)
      TKTLBR=(DSFTB(IDL16,IDL17)/5280.0)/
     1((TKTLWD(IDL18)*(1.0+TKTCF(IDL16,IDL17)))/2.0)
CJK
CJK
      TKCT=TRUCK CYCLE TIME; TKTEWM=TRAEMPTY TIME
CJK   OVER NON-WOODS ROAD;  TKTLWM=TRAVEL LOADED TIME
CJK   OVER NON-WOODS ROAD;  TKTEBR=TRAVEL TIME EMPTY
CJK   OVER WOODS OR BUILT ROAD; TKTLBR=TRAVEL TIME
CJK   LOADED OVER BUILT OR WOODS ROAD

CJK
      TKCT=(TKTEWM+TKTLWM+TKTEBR+TKTLBR+(TKFTPC(IDL18)/60.0))
     1/TKEF(IDL18)
      TKCYC=VOLML(IDL16,IDL17)/TKVOL(IDL18)
      TKH=TKCT*TKCYC
      SMTKH=SMTKH+(1.0/TKH)
      WRITE(KW,3700)IDL16,IDL17,IDL18,TKCT,TKCYC,TKH
 3700 FORMAT(4X,I4,5X,I4,4X,I4,1X,F7.2,1X,F9.1,F10.2)
 3750 CONTINUE
CJK
CJK
CJK   SMTKHL=THE TIME IT WOULD TAKE IF ALL TRUCKS WORKED
CJK   TOGETHER
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```
CJK
CJK
      SMTKHL=1.0/SMTKH
      SMTKLH=SMTKLH+SMTKHL
      SMTKLC=SMTKLH*SMTKHC
      SMTKMH=SMTKMH+SMTKLH
      IF(NTRK.GT.1)WRITE(KW,3800)IDL16,IDL17,SMTKLH,SMTKLC
 3800 FORMAT(4X,I4,5X,I4,38X,F10.2,F9.2)
 3850 CONTINUE
      SMTKMC=SMTKMH*SMTKHC
      LOGMET(5,IDL16)=SMTKMH
      WRITE(KW,3900)IDL16,SMTKMH,SMTKMC
 3900 FORMAT(4X,I4,67X,F11.2,F11.2,/)
 3950 CONTINUE
      WRITE(KW,4000)
 4000 FORMAT(/,2X,99('*'))
      IF(ICTRAT.EQ.0)GO TO 4500
      WRITE(KW,4250)
 4250   FORMAT(2(/),2X,21('*'),/,
     12X,'CONSTRAINT',/,8X,'CODE',/,2X,'1= ROAD HR',/,
     22X,'2= LAND HR',6X,'UPPER',/,2X,'3= SKID HR',6X,'BOUND',/,
     32X,'4= TRUK HR',6X,'VALUE',/)
      DO 4400 IDL23=1,ICTRAT
      K=IDL23+7
      JCONSC=NMETH+ICTRAT+12
CJK
CJK
CJK  ********** CARD TYPE 17 ****************************
CJK
CJK
CJK     ICSTFO=CONSTRAINT CODE; CSTVAL=VALUE OF THIS
CJK     CONSTRAINT
CJK
CJK
      READ(KR,4300)ICSTFO,CSTVAL
 4300 FORMAT(I1,1X,F9.1)
      MCONSC=JCONSC-(4-ICSTFO)
CJK UPPER BOUND ROAD CONSTRUCTION HOURS
CJK
      IF(ICSTFO.EQ.1)P(K)=CSTVAL
      IF(ICSTFO.EQ.1)A(K,MCONSC)=1.0
      IF(ICSTFO.EQ.1)JVAR(K)=1
CJK
CJK UPPER BOUND FOR WEIGHTED LANDING CONST. & MOVING
CJK
      IF(ICSTFO.EQ.2)P(K)=CSTVAL
      IF(ICSTFO.EQ.2)A(K,MCONSC)=1.0
      IF(ICSTFO.EQ.2)JVAR(K)=2
CJK
CJK UPPER BOUND FOR SKIDDING HOURS
CJK
      IF(ICSTFO.EQ.3)P(K)=CSTVAL
      IF(ICSTFO.EQ.3)A(K,MCONSC)=1.0
      IF(ICSTFO.EQ.3)JVAR(K)=3
CJK
CJK  UPPER BOUND FOR TRUCKING HOURS
CJK
      IF(ICSTFO.EQ.4)P(K)=CSTVAL
      IF(ICSTFO.EQ.4)A(K,MCONSC)=1.0
      IF(ICSTFO.EQ.4)JVAR(K)=4
      WRITE(KW,4350)ICSTFO,CSTVAL
 4350 FORMAT(6X,I2,7X,F8.0)
 4400 CONTINUE
      WRITE(KW,4450)
 4450 FORMAT(/,2X 21('*'),/)
 4500 CONTINUE
      IF(IUNIT.EQ.1)TOTLVL=HARVOL/2000.0
      IF(IUNIT.EQ.2)TOTLVL=HARVOL/1000.0
      IF(IUNIT.EQ.3)TOTLVL=HARVOL/100.0
      IF(IUNIT.EQ.4)TOTLVL=HARVOL/1.0
      WRITE(KW,4700)
 4700 FORMAT(1H1,/,64X,'METHOD SUMMARY',/,1X,127('*'),/,31X,
     1'LANDING CONSTRUCTION',58X,'TOTAL',6X,
     2'METHOD',/,9X,'ROAD CONSTRUCTION',5X,'AND',2X,'SYSTEM',
     33X,'MOVING',10X,'SKIDDING',15X,'TRUCKING',16X,'METHOD',
     42X,'HARVESTING',/,1X,'METH',2X,21('-'),3X,21('-'),3X,
     521('-'),3X,21('-'),4X,'HARVESTING',8X,'UNIT',/,
     63X,'NO',2X,'HOURS',6X,'$$$',2X,'$/VOL',3X,'HOURS',6X,
     7'$$$',2X,'$/VOL',3X,'HOURS',6X,'$$$',2X,'$/VOL',3X,
     8'HOURS',6X,'$$$',2X,'$/VOL',9X,'COSTS',7X,'COSTS',/)
      DO 4900 IDL30=1,NMETH
      SOUT01=LOGMET(2,IDL30)*SMDZHC
      SOUT02=SOUT01/TOTLVL
      SOUT03=LOGMET(3,IDL30)*(DZRHC(ILDZR)+SYSMHC)
      SOUT04=SOUT03/TOTLVL
      SOUT05=LOGMET(4,IDL30)*SMSKHC
      SOUT06=SOUT05/TOTLVL
      SOUT07=LOGMET(5,IDL30)*SMTKHC
      SOUT08=SOUT07/TOTLVL
      SOUT09=SOUT01+SOUT03+SOUT05+SOUT07
      SOUT10=SOUT09/TOTLVL
      WRITE(KW,4800)IDL30,LOGMET(2,IDL30),SOUT01,SOUT02,
     1LOGMET(3,IDL30),SOUT03,SOUT04,LOGMET(4,IDL30),
     2SOUT05,SOUT06,LOGMET(5,IDL30),SOUT07,SOUT08,
     3SOUT09,SOUT10
 4800 FORMAT(2X,I3,1X,F6.0,1X,F8.0,1X,F6.0,2X,F6.0,1X,
     1F8.0,F7.0,2X,F6.0,1X,F8.0,1X,F6.0,2X,F6.0,1X,
     2F8.0,1X,F6.0,2X,F12.2,2X,F10.2)
 4900 CONTINUE
      WRITE(KW,5000)
 5000 FORMAT(/,127('*'))
CJK
CJK
CJK        ############# SECTION 2 ###################
CJK
CJK
CWC
CWC  FORMAT STATEMENTS USED IN RAVINDRIN'S PROGRAM
CWC
    1 FORMAT(1H1 /,3X,'ITERATION NO=',I5)
C 112 FORMAT(1X,I2,4I12/(13X,4I12)/(13X,4I12)/(13X,2I12))
C 121 FORMAT(1X,I2,F8.2,3X,4F12.2/(14X,4F12.2)/(14X,4F12.2)/
C    2(14X,2F12.2))
C 122 FORMAT(5X,4F13.1/(5X,3F13.1))
C 123 FORMAT(1X,F12.1,1X,4F12.1/(4X,4F12.1)/(4X,4F12.1)/(
C    34X,2F12.1))
C 325 FORMAT( 1X/7X,8HSOLUTION,10X,7HTABLEAU)
C 326 FORMAT( 1X,14HVARIABLE COSTS,2X,3F15.4/(2X,4F15.4)/(2X
C    4,4F15.4)/(2X,3F15.4))
  102 FORMAT(1X,5X,37HTHE OBJECTIVE FUNCTION IS NIT BOUNDED)
  335 FORMAT(1HA)
      IP1 = 1
      IP2 = 1
CWC
CWC  M = NUMBER OF COLUMNS IN BASIS
CWC  N = NUMBER CF COLUMNS IN "A" MATRIX
CWC
      M= ICTRAT+7
      M2 = NMETH+10
      N = NMETH+5+M
      N2 = NMETH+5
      M3 = M+1
      N9 = NMETH+M
CWC
CWC  IREP = 0 IF ONLY FIRST TABLEAU IS TO BE PRINTED
CWC       = 1 IF ALL TABLEAUS SHOULD BE PRINTED
CWC
      IREP = 1
      IT=0
      WRITE(KW,335)
      EP=.5E-6
CWC
CWC  "JVAR" ARRAY CONTAINS A NUMBER CORRESPONDING TO EACH COLUMN
CWC  IN THE "'A" MATRIX. DUE TO THE METHOD OF INPUT INTO M
CWC  MATRIX, M FIRST M COLUMNS (BASIS) OF THE MATRIX MUST
CWC  BE NUMBERED TO REFLECT THE FACT THAT IT SHOULD APPEAR
CWC  ATM ED OF M MATRIX.
CWC
      DO 3 I=1,M
      JVAR(I) = N2+I
    3 CONTINUE
CWC
CWC  NUMBER OTHER COLUMNS AS THOUGH THEY WERE AT FRONT OF MATRIX
CWC
      DO 4 I=M3,N
      JVAR(I)=I-M
    4 CONTINUE
      K=M3
CWC
CWC  SET PRODUCT PRICE IN OBJECTIVE FUNCTION
CWC
      C(K) = PRODPC
      K = NMETH+M3+1
CWC
CWC  SET ROAD EQUIPMENT HOURLY COST IN OBJECTIVE FUNCTION
CWC
      C(K) = -SMDZHC
      K = K+1
CWC
CWC  SET LANDING CONSTRUCTION HOURLY COST IN OBJECTIVE FUNCTION
CWC  LANDING CONSTRUCTION HOURLY COST = ROAD EQUIPMENT HOURLY
CWC     COST + SYSTEM MOVE HOURLY COST
CWC
      C(K) = -DZRHC(ILDZR)-SYSMHC
      K = K+1
CJK
CJK
CJK  SMSKHC= SUM OF HOURLY SKIDDER COSTS
CJK  SMTKHC= SUM OF HOURLY TRUCKING COSTS
CJK
CJK
      C(K) = -SMSKHC
      K = K+1
      C(K) = -SMTKHC
      K = K+1
CWC
CWC  SET RIGHT HAND CONSTANTS OF FIRST FIVE EQUATIONS -
CWC  EQUAL TO 0.0
CWC
      DO 778 I=1,5
      P(I) = 0.0
      B(I) = 0.0
  778 CONTINUE
      A(1,M3)=1.0
      K9=M+NMETH+1
```

```
      K8=M+2
CWC
CWC STORE DATA IN "LOGMET" MATRIX IN "A" MATRIX lo BE USED
CWC IN LP
CWC
      DO 317 I=K8,K9
      DO 242 J=1,M
      K=I-M-1
      A(J,I) = LOGMET(J,K)
  242 CONTINUE
  317 CONTINUE
CWC
CWC STORE Z VALUES INTO "A" MATRIX
CWC
      K9 = K9+1
      K8 = K9+3
      J=1
      DO 467 I=K9,K8
      J=J+1
      A(J,I)=-1.0
  467 CONTINUE
CWC
CWC STORE CONSTRAINT RELATING To TRACK VOLUME INTO "A" MATRIX
CWC
      A(6,M3)=1.0
CWC
CWC STORE TRACK VOLUME INTO "B" MATRIX
CWC
      P(6)=TOTLVL
      B(6)=TOTLVL
      M4 = M3+1
CWC
CWC STORE CONSTRAINT RESTRICTING SUM OF METHODS m EQUAL ONE
CWC
      DO 992 K=1,NMETH
      A(7,M4) = 1.0
      M4 = M4+1
  992 CONTINUE
CWC
CWC STORE 1.0 INTO "B" MATRIX
CWC
      P(7) = 1.0
      B(7) = 1.0
      m 5 J=1,N
      JJ=JVAR(J)
    5 CC(JJ)=C(J)
      L=M+1
      m 301 I=1,N
      CI(I)=C(I)
      IVAR(I)=JVAR(I)
  301 CONTINUE
CWC
CWC STORE BASIS INTO MATRIX
CWC
      m 444 I=1,M
      A(I,I)=1.0
  444 CONTINUE
  194 CMZM=-9.E30
CWC
CWC  CALCULATE C-BAR ROW
CWC OUTER DO LOOP CONTROLS COLUMNS IN "A" MATRIX
CWC  INNER DO LOOP CONTROLS SUMMING OF EACH ELEMENT OF COLUMN
CWC
      m 74 JVC=1,N
      Z=0.0
CWC "Z" I s PRODUCT OF "A" ARRAY COLUMN TIMES CB ELEMENTS OF MATRIX
CWC
      m 75 I=1,M
   75 Z=Z+A(I,JVC)*CI(I)
CWC
CWC  ENT IS C-BAR ELEMENT FOR THAT COLUMN
CWC  CMZ IS ARRAY THAT HOLDS C-BAR ELEMENTS
CWC
      ENT=C(JVC)-Z
      CMZ(JVC)=ENT
CWC
CWC  FIND LARGEST VALUE IN C-BAR ROW TO USE AS PIVOT COLUMN
CWC  STORE VALUE OF LARGEST C-BAR ELEMENT IN CMZM AND STORE
CWC  PIVOT COLUMN NUMBER IN KOUT
CWC
      IF(CMZM.GT.ENT)GO m 74
      CMZM=ENT
      KOUT=JVC
   74 CONTINUE
CWC
CWC INCREMENT ITERATION COUNTER AND WRITE ITERATION MESSAGE
CWC
      IT=IT+1
      WRITE(KW,1)IT
      IF(IREP.EQ.0)GO m 25
CWC
CWC CALCULATE Z VALUE AND STORE IN VARIABLE "VALUE"
CWC
  601 VALUE=0.0
      m 110 I=1,M
  110 VALUE=VALUE+P(I)*CI(I)
CWC
CWC WRITE OUT "A" MATRIX AS INPUTTED INTO LP PROGRAM
CWC
CJK
CJK   DEBUG FORMAT OPTION:::: THIS FORMAT IS HARD m
CJK   FOLLOW BUT SHOWS THE INPUT MATRIX IN THE FORM
CJK   USED BY RAVANDRINA :: SLACKS AND SURPLUS FIRST
CJK   MN NORMAL LP VALUES
CJHK
      IF(LPCDE.EQ.1)WRITE(KW,6001)M,N
 6001 FORMAT(25X,'ROWS 1 THRU ',I3,' PM COLUMNS 1 THRU',I3,
     1'  IN RAVINDRAN LP MATRIX',/)
      m 2456 K=1,M
      IF(LPCDE.EQ.1)WRITE(KW,8456) (A(K,JHA),JHA=1,N)
 8456 FGWTh0.2)
 2456 CONTINUE
 2457 CONTINUE
CWC
CWC WRITE OUT TOP THREE OR FOUR LINES OF TABLEAU WHICH DOES
CWC  NOT VARY BY NUMBER OF METHODS
CWC
      WRITE(KW,6000)
 6000 FORMAT(/,1X,128('*'))
      WRITE(KW,6010)
 6010 FORMAT(1X,'*',4X,'*  ',7X,'',99X,'',11X,'*')
      K2=NMETH+2
      K2=NMETH+M3+1
      WRITE(KW,6020) C(M3),(C(I),I=K2,N)
 6020 FORMAT(1X,'*',4X,'* *',2X,'CJ',2X,'*',1X,F8.2,49X,4(1X,F9.2),
     11X '*',3X 'RIGHT',3X,'*')
      WRITE(KW,6030)
 6030 FORMAT(1X,'*',4X,'* 8*',5X,'*',99X,'*',11X,'*')
      WRITE(KW,6040)
 6040 FORMAT(1X,'*',4X,'* A *',4X,101('*'),3X,'HAND',4X,'*')
      N3 = NMETH-1
CWC
CWC  BRANCH TO STATEMENT NUMBER AND COMPLETE OUTPUT ACCORDING
CWC  TO THE NUMBER OF METHODS
CWC
      GO m (7000,7010,7020),N3
CJK
CJK
CJK CONTROL GOES TO STATEMENT NUMBER 7000 IF 2 METHODS
CJK CONTROL GOES TO STATEMENT NUMBER 7010 IF 3 MEHTODS
CJK CONTROL GOES TO STATEMENT NUMBER 7020 IF 4 METHODS
CJK
CJK
CWC
CWC  WRITE OUT TABLEAU FOR COMPARISON OF TWO METHODS
CWC
 7000 WRITE(KW,6060)
 6060 FORMAT(1X,'*',5X,'* S *  *',9X,'* METHOD * METHOD *'
     1,29X,'*  $/HR * $/HR * $/HR *  $/HR *' 11X ,'*')
      WRITE(KW,6070)
 6070 FORMAT(1X,'*',2X,'CB',2X,'*',2X,'I • • (YO)  *', 4X -'I' 4X,
     1'*', 4X '2' 4X '*',29X,'* ROADS * LAND * SKID *',
     2' TRUCK * CONSTANTS *')
      WRITE(KW,6080)
 6080 FORMAT(1X,'*',7X,'* S  *  *',9X,'* (M1) *  (M2) *',29X,
     1'*  (Z1) •  (Z2) *  (Z3) *  (Z4)  *',11X,'*')
      WRITE(KW,6050)
 6050 FORMAT(1X,128('*'))
      WRITE(KW,6115)
 6115 FORMAT(1X,'*',9X,'*',4X,'*',99X,'*',11X,'*')
CWC
CWC  DO LOOP CONTROLS PRINTING OF EACH ROW IN MATRIX
CWC
      m 8000 I=1,M
      K=IVAR(I)
CWC
CWC VARIABLES USED m CONTROL OUTPUT.  YOU HAVE m THINK
CWC  TO FIGURE OUT THE VALUES THAT NEED TO BE ASSIGNED TO
CWC  THE VARIABLES
CWC
      N5=N9+1
      N6=N5+1
      M4=M3+1
CJK
CJK  OUTPUT FORMAT FOR LP IN CONVEX FORM BY METHOD
CJK  AND HOURS AND NEAT HEADINGS
CJK
      WRITE(KW,6090) C(K),IVAR(I),A(I,M3),(A(I,J),J=M4,N5),(A(I,J),
     1J=N6,N),P(I)
 6090 FORMAT(1X,'*',1X,F7.2,1X,'*',1X,'X',I2,'*',3F10.2,
     129X,4F10.2,'*',1X,F9.2,1X,'*')
 8000 CONTINUE
      WRITE(KW,6115)
      WRITE(KW, 6100)
 6100 FORMAT(1X,128('*'))
      WRITE(KW,6110)
 6110 FORMAT(1X,'*',14X,'*',99X,'*',4X,'Z =',4X,'*')
CWC
CWC  WRITE C-BAR ROW OUT IN TABLEAU
CWC
      WRITE(KW,6120) (CMZ(J),J=M3,N),VALUE
 6120 FORMAT(1X,'*',2X,'C-BAR ROW',3X,'*',3F10.2,'*',28X,4F10.2,1X,
     1F11.0,'*')
      GO TO 7040
```

```
7010 WRITE(KW,6130)
CWC
CWC  WRITE OUT TABLEAU FOR COMPARISON OF THREE METHODS
CWC
 6130 FORMAT(1X,'*',5X,'* S *',3X,'* SELLING ',3('* METHOD '),'*',
     120X,3('*  $/HR  '),'*',3X,'$/HR',1X,'*',11X,'*')
      WRITE(KW,6140)
 6140  FORMAT(1X,'*',2X,'CB',2X,'*',2X,'I * * PRICE $ *',4X,'1',4X,
     1'*',4X,'2',4X,'*',4X,'3',4X,'*',20X,'* ROADS * LAND *',
     2'           SKID * TRUCK * CONSTANTS *')
      WRITE(KW,6150)
 6150 FORMAT(1X,'*',7X,'* S * *  (Y0)  *  (M1)  *  (M2)  *',2X,
     1'(M3)  *',20X,'*',3X,'(Z1)  *  (Z2)  *  (Z3)  *  (Z4) *',
     211X,'*',/,1X,128('*'))
CWC
CWC  DO LOOP CONTROLS PRINTING OF EACH ROW
CWC
       DO 8010 I=1,M
       K = IVAR(I)
CWC
CWC  VARIABLES USED TO CONTROL OUTPUT
CWC
       N5=N9+1
       N6=N5+1
       M4=M3+1
       WRITE(KW,6160) C(K),IVAR(I),A(I,M3),(A(I,J),J=M4,N5),(A(I,J),
     1J=N6,N),P(I)
 6160 FORMAT(1X,'*',1X,F7.2,1X,'*',1X,'X',I2,'*',4F10.2,20X,4F10.2,
     1F10.2,1X,'*')
 8010 CONTINUE
       WRITE(KW,6115)
       WRITE(KW,6100)
       WRITE(KW,6110)
CWC
CWC  PRINTS OUT C-BAR ROW
CWC
       WRITE(KW,6190) (CMZ(J),J=M3,N),VALUE
 6190 FORMAT(1X,'*',2X,'C-BAR ROW',3X,'*',4F10.2,20X,4F10.2,
     1F11.0,'*')
       GO TO 7040
CWC
CWC  WRITE OUT TABLEAU  FOR COMPARISON OF FOUR METHODS
CWC
 7020 WRITE(KW,6200)
 6200  FORMAT(1X,'*',5X,'* S *',3X,'* SELLING  ',4('* METHOD '),'*',
     19X,4('*  $/HR  '),'*',11X,'*')
       WRITE(KW,6210)
 6210 FORMAT(1X,'*',2X,'CB',2X,'*',2X,'I * * PRICE $ *',4X,'1',4X,
     1'*',4X,'2',4X,'*',4X,'3',4X,'*',4X,'4',4X,'*',9X,
     2'*  ROADS  *   LAND  *   SKID  *  TRUCK  * CONSTANTS  *')
        WRITE(KW,6220)
 6220 FORMAT(1X,'*',7X,'* S * *  (Y0)  *  (M1)  *  (M2)  *',
     12X,'(M3)  *  (M4)  *',9X,'*  (Z1)  *  (Z2)  *  (Z3)  *',
     23X,'(Z4)  *',11X,'*',/)
       WRITE(KW,6100)
       WRITE(KW,6115)
       DO 8020 I=1,M
CWC
CWC VARIABLES USED TO CONTROL OUTPUT
CWC
       K = IVAR(I)
       N5 = N9+1
       N6 = N5+1
       M4 = M3+1
       WRITE(KW,6230) C(K),IVAR(I),A(I,M3),(A(I,J),J=M4,N5),(A(I,J),
     1J=N6,N),P(I)
 6230  FORMAT(1X,'*',1X,F7.2,1X,'*',1X,'X',I2,'*',5F10.2,9X,4F10.2,
     1'*',1X,F9.2,1X,'*')
 8020 CONTINUE
       WRITE(KW,6115)
       WRITE(KW,6100)
       WRITE(KW,6110)
CWC
CWC  PRINTS OUT C BAR ROW
CWC
       WRITE(KW,6260) (CMZ(J),J=M3,N),VALUE
 6260 FORMAT(1X,'*',2X,'C-BAR ROW',3X,'*',5F10.2,9X,4F10.2,'*',
     1F11.0,'*')
 7040 CONTINUE
       WRITE(KW,6131)
 6131 FORMAT(1X,128('*'))
CWC
CWC  CHECK FOR OPTIMAL SOLUTION
CWC
       IF(CMZM.LT.EP)GO TO 192
       GO TO 801
   25  IF(IT.EQ.1)GO TO 601
   26  IF(CMZM.LT.EP)GO TO 191
  801  THETA=9.E30
CWC
CWC  DETERMINE PIVOT ELEMENT IN COLUMN.
CWC  DO LOOP CONTROLS SEARCH THROUGH ROWS
CWC
       DO 812 I=1,M
       IF(A(I,KOUT).LE.EP)GO TO 812
       TH=P(I)/A(I,KOUT)
       IF(THETA.LT.TH)GO TO 812
CWC
CWC  VARIABLE THETA CONTAINS VALUE OF PIVOT ELEMENT AFTER DIVISION.
CWC  IRIN  CONTAINS THE NUMBER OF THE PIVOT ROW.
CWC
       THETA=TH
       IRIN=I
  812  CONTINUE
CWC
CWC  CHECK FOR UNBOUNDED SOLUTION.   IF FOUND WITE OUT MESSAGE
CWC  AND END PROGRAM
CWC
       IF(THETA.LT.9.0E20)GO TO 507
       WRITE(KW,102)
       GO TO 192
  191  IF(IREP.EQ.0)GO TO 601
CWC
CWC  VARIABLE PIVOT CONTAINS PIVOT ELEMENT
CWC
  507  PIVOT=A(IRIN,KOUT)
       P(IRIN)=P(IRIN)/PIVOT
CWC
CWC  DIVIDE PIVOT ROW BY PIVOT ELEMENT
CWC
       DO 521 J=1,N
  521  A(IRIN,J)=A(IRIN,J)/PIVOT
CWC
CWC  NECESSARY MATRIX DIVISION AFTER PIVOT ELEMENT AND ROW
CWC  IS FOUND. OUTER LOOP CONTROLS COLUMNS; INNER LOOP
CWC  CONTROLS ROWS
CWC
       DO 522 J=1,N
       IF(J.EQ.KOUT)GO TO 522
       DO 523 I=1,M
       IF(I.EQ.IRIN)GO TO 523
       A(I,J)=A(I,J)-A(I,KOUT)*A(IRIN,J)
  523  CONTINUE
  522  CONTINUE
       DO 529 I=1,M
CWC
CWC  IF  STATEMENT PROTECTS PIVOT ELEMENT
CWC
       IF(I.EQ.IRIN)GO TO 529
CWC
CWC  CALCULATE RIGHT-HAND CONSTANTS
CWC
       P(I)=P(I)-P(IRIN)*A(I,KOUT)
CWC
CWC  ZERO OUT PIVOT COLUMN
CWC
       A(I,KOUT)=0.0
  529  CONTINUE
       EP=EP+.5E-6
       CI(IRIN)=C(KOUT)
       IVAR(IRIN)=JVAR(KOUT)
CWC
CWC  SET PIVOT ELEMENT TO 1.0
CWC
       A(IRIN,KOUT)=1.0
       GO TO 194
CWC
CWC  WRITE OUT SUMMARY OF METHODS PICKED FROM LP
CWC
  192  CONTINUE
       II=0
CWC
CWC  ITOT KEEPS TRACK OF NUMBER OF METHODS PICKED
CWC  TSSUM IS THE SUM OF THE PROPORTION OF EACH METHOD PICKED
CWC
       ITOT=0
       INMIP=0
       TSSUM=0.0
       DO 9431 IHELPM=1,25
 9431  CONTINUE
       DO 9433 IHELPY=1,4
       IARR(IHELPY)=0
       RC(IHELPY)=0.0
       LD(IHELPY)=0.0
       SK(IHELPY)=0.0
       TK(IHELPY)=0.0
 9433  CONTINUE
       SUMRPH=0.0
       SUMRPC=0.0
       SUMLPH=0.0
       SUMLPC=0.0
       SUMSPH=0.0
       SUMSPC=0.0
       SUMTPH=0.0
       SUMTPC=0.0
       SUMTOT=0.0
       WRITE(KW,6500)
 6500  FORMAT(1X,16('*'),57X,'***',40X,12('*'),/,1X,16('*'),
     157X,'***',40X,12('*'),/,1X,16('*'),9X,
     2'ABOVE VALUES IN C-BAR ROW',23X,'***',6X,
     3'ABOVE VALUES IN C-BAR ROW',9X,12('*'),/,1X,16('*'),
     49X,'ARE    PENALTY COSTS',31X,'***',6X,
     5'ARE SHADOW PRICES',17X,12('*'),/,1X,16('*'),57X,'***',
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     640X,12('*'),/,1X,16('*'),57X,'***',40X,12('*'),
     7/,1X,128('*'))
      WRITE(KW,8042)IT
 8042 FORMAT(1H1,2(/),37X,'AFTER ',I3,' ITERATIONS THE OPTIMUM',
     11X,'SOLUTION CONSISTED OF:',
     1/,1X,128('*'),/,25X,'ROAD',5X,'ROAD',4X,
     2'LANDING CONST',4X,'LANDING CONST',52X,'TOTAL',/,
     31X,'METHOD',6X,'METHOD',5X,'CONST',4X,'CONST',4X,
     4'AND',4X,'SYSTEM',4X,'AND',4X,'SYSTEM',3X,'SKIDDING',
     54X,'SKIDDING',4X,'TRUCKING',4X,'TRUCKING',4X,'METHOD',
     6/,6X,'#',2X,'PROPORTION',
     15X,'HOURS',4X,'COSTS',12X,'HOURS',12X,'COSTS',
     76X,'HOURS',7X,'COSTS',7X,'HOURS',7X,'COSTS',5X,'COSTS',/)
      DO 1012 I=1,M
      DO 1012 K=1,NMETH
      K2=K+1
      IF(IVAR(I).NE.K2) GO m 1012
      I1=I1+1
      IARR(I1)=IVAR(I)-1
      TSSUM=TSSUM+P(I)
      ITOT=ITOT+1
      PROP(I1)=P(I)
      I2P=IARR(I1)
      RC(I2P)=LOGMET(2,I2P)*PROP(I1)
      LD(I2P)=LOGMET(3,I2P)*PROP(I1)
      SK(I2P)=LOGMET(4,I2P)*PROP(I1)
      TK(I2P)=LOGMET(5,I2P)*PROP(I1)
      INMIP=INMIP+1
      ROADMC=RC(I2P)*SMDZHC
      LAMDMC=LD(I2P)*(DZRHC(ILDZR)+SYSMHC)
      SKIDMC=SK(I2P)*SMSKHC
      TRUKMC=TK(I2P)*SMTKHC
      SUMRPH=SUMRPH+RC(I2P)
      SUMRPC=SUMRPC+ROADMC
      SUMLPH=SUMLPH+LD(I2P)
      SUMLPC=SUMLPC+LAMDMC
      SUMSPH=SUMSPH+SK(I2P)
      SUMSPC=SUMSPC+SKIDMC
      SUMTPH=SUMTPH+TK(I2P)
      SUMTPC=SUMTPC+TRUKMC
      TOTHRM=ROADMC+LAMDMC+SKIDMC+TRUKMC
      SUMTOT=SUMTOT+TOTHRM
      WRITE(KW,8047)IARR(I1),PROP(I1),RC(I2P),ROADMC,LD(I2P),
     1LAMDMC,SK(I2P),SKIDMC,TK(I2P),TRUKMC,TOTHRM
 8047 FORMAT(3X,I4,6X,F6.2,1X,F9.1,1X,F8.0,8X,F9.1,9X,F8.0,2X,
     1F9.0,4X,F8.0,3X,F9.1,4X,F8.0,1X,F9.0)
 1012 CONTINUE
      WRITE(KW,8048)
 8048 FORMAT(12X,7('-'),1X,9('-'),1X,8('-'),8X,9('-'),9X,
     18('-'),2X,9('-'),4X,8('-'),3X,9('-'),4X,8('-'),1X,9('-'))
      WRITE(KW,8049)TSSUM,SUMRPH,SUMRPC,SUMLPH,SUMLPC,SUMSPH,
     1SUMSPC,SUMTPH,SUMTPC,SUMTOT
 8049 FORMAT(1X,'TOTALS:',5X,F6.2,1X,F9.1,1X,F8.0,8X,F9.1,9X,
     1F8.0,2X,F9.0,4X,F8.0,3X,F9.1,4X,F8.0,1X,F9.0,/,
     21X,128('*'))
      GROSSV=PROCPC*TOTLVL
      GRSMHC=GROSSV-VALUE
      UNITHC=VALUE/TOTLVL
      GMNHUC=PROCPC-UNITHC
      WRITE(KW,8055)GROSSV,PROCPC
 8055 FORMAT(2(/),1X,91('*'),/,1X,'(A) TOTAL DELIVERD PRICE',
     11X,'OF HARVESTED TIMBER:',2X,F13.0,7X,'UNIT PRICE:',3X,F9.2)
      WRITE(KW,8060)GRSMHC,GMNHUC
 8060 FORMAT(1X,'(B)TOTAL HARVESTING COSTS (THOSE CONSIDERED):'
     1,1X,F13.0,7X,'UNIT COSTS:',3X,F9.2,/,54X,7('-'),24X,
     27('-'))
      WRITE(KW,8070)VALUE,UNITHC
 8070 FORMAT(26X,'DIFFERENCE: (A)-(B):',2X,F13.0,21X,F9.2,/,
     191('*'))
      CALL SENS(N,M)
      STOP
      END
      SUBROUTINE SENS(N,M)
C
C*****THIS SUBROUTINE IS THE EXECUTIVE ROUTINE m INITIALIZE THE
C     SENSITIVITY ANALYSIS.
C
      COMMON C(25),P(25),CMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
     1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
     2,B(25),CC(25),JVAR(25)
     3,IARR(4),PROP(4),RC(4),LD(4),SK(4),TK(4)
C
C*****FIRST, THE LIMITS ON EACH C(J) ARE FOUND.  IF X(L) IS A  BASIC
C     VARIABLE, MN SUBROUTINE CBAS IS CALLED, OTHERWISE SUBROUTINE
C     CNONB IS USED FOR NONBASIC X(L). IF X(L) IS BASIC, NCUE IS SET
c     m 1. OTHERWISE NCUE REMAINS 0.
C
      K=0
      KW=6
    5 NCUE=0
      K=K+1
      L=JVAR(K)
      IF(K.GT.N)GO m 16
      DO lo I=1,M
      KV=IVAR(I)
      IF(L-KV)10,20,10
   20 NCUE=1
   lo CONTINUE
   25 CAIF(NCUE-CNONB(K,N30) 25
      GO TO 5
   30 CALL CBAS(K,N,M)
      GO TO 5
C
C*****NOW,SUBROUTINE BRANG IS CALLED m DETERMINE THE RANGES ON THE
c     RIGHT HAND SIDE CONSTANTS E(I).
C
   15 CALL BRANG(N,M)
C
C*****THE FINAL STEP IS m WRITE THE REPORT. FIRST, ME SHADOW PRICES
C     AND PENALTY COSTS ARE WRITTEN.  #XT, THE RANGES ON M BASIC
c     PM NONBASIC C(J) ARE WRITTEN. THEN, THE B(I) RANGES ARE
C     DISPLAYED, AND THE SENSITIVITY ANALYSIS I S COMPLETED. DURING THE
c     WRITE ROUTINES, THE SUBROUTINE CHECK I S CALLED, WHICH DETERMINES
C     IF X(J) IS BASIC CR NONBASIC IN THE OPTIMUM TABLEAU.
c
      WRITE(KW,100)
      WRITE(KW,1000)
      WRITE(KW,101)
      WRITE(KW,102)
     KS)
1   1  K=K+1
      IF(K.GT.N) GO m 31
      'XL CHECK(K,NQUE,N,M)
      IF(NQUE-1) 21,11,21
   21 WRITE(KW,103) JVAR(K),PCOST(K)
CJK
CJK
CJK   WRITES OUT NON-BASIC VARIABLES AND PENALTY COSTS
CJK
CJK
CJK
      GO m 11
   31 WRITE(KW,149)
CJK
CJK
CJK    WRITES OUT ROW NUMBER AND SHADOW PRICES
CJK
CJK
      DO 22 I=1,M
   22 WRITE(KW,103) I,ZJ(I)
      WRITE(KW,104)
      WRITE(KW,105)
      K=0
   40 K=K+1
      IF(K.GT.N) GO m 60
      CALL CHECK(K,NQUE,N,M)
      IF(NQUE-1) 50,40,50
   50 WRITE(KW,106) JVAR(K),CL(K)
CJK
CJK
CJK   WRITES CM RANGES ON NON-BASIC C(J), VARIABLE CODE
CJK   AND ITS LOWER LIMIT
CJK
CJK
      GO TO 40
   60 WRITE(KW,107)
      WRITE(KW,108)
      K=0
   70 K=K+1
      IF(K.GT.N) GO m 90
      CALL CHECK(K,NQUE,N,M)
      IF(NQUE) 70,70,80
   80 WRITE(KW,109)JVAR(K),CLO(K),CUP(K)
CJK
CJK
CJK WRITES OUT RANGES CN BASIC C(J), VARIABLE LOWER LWT, AND
CJK VARIABLE UPPER LIMIT
CJK
CJK
      GO TO 70
   90 WRITE(KW,110)
      WRITE(KW,111)
      DO 95 I=1,M
      WRITE(KW,112) I,BLO(I),BUP(I)
CJK
CJK
CJK WRITES OUT VARIABLE CODE AND UPPER AND LOWER LIMIT OF B(I)
CJK
CJK
   95 CONTINUE
  100 FORMAT(1H1,25X,'SENSITIVITY ANALYSIS',2(/),
     110X,'NOTE:. VARIABLE CUE NUMBERS USED IN SENSITIVITY',/,
     210X,'ANALYSIS ARE NOT EASY m CORRELATE WITH OUTPUT',/,
     310X,'COLUMNS AND ROWS FROM LP MATRIX',//,
     410X,'USERS FAMILAR WITH LP SHOULD MAKE CHANGES IN'./,
     510X,'INPUT COSTS (CJ) AND RESOURCE LIMITS (BJ) TO',/,
     610X,'BECOME FAMILAR WITH THE SENSITIVITY ANALYSIS AS IT',/,
     710X,'APPLIES TO THE CONVEX-ISOQUANT-METHOD FORMULATION',/,
     810X,'USED IN L-O-S-T',//)
m  1 FORMAT(10X,'NON-BASIC',12X,'PENALTY')
  102 FORMAT(10X,'VARIABLES',13X,'COST',/)
  103 FORMAT(13X,I2,13X,F12.3)
  104 FORMAT(4(/),3X,'RANGES ON NON-BASIC C(J)',/)
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  105 FORMAT(10X,'VARIABLE',11X,'LOWER LIMIT' ,/)
  106 FORMAT(13X,I2,14X,F11.3)
  107 FORMAT(4(/),3X,'RANGES ON BASIC C(J)',/)
  108 FORMAT(10X,'VARIABLE',11X,'LOWER LIMIT',11X,'UPPER LIMIT' ,/)
  109 FORMAT(13X,I2,14X,F11.3,11X,F11.3)
  110 FORMAT(4(/),3X,'RANGES ON B(I)',/)
  111 FORMAT(14X,'I',14X,'LOWER LIMIT',11X,'UPPER LIMIT' ,/)
  112 FORMAT(13X,I2,14X,F11.3,11X,F11.3)
  149 FORMAT(3(/),13X,'ROW',15X,'SHADOW',/,12X,'NUMBER',13X,
     1'PRICES',/)
 1000 FORMAT(1X,'SHADOW PRICES ARE CHANGE IN OBJECTIVE FUNCTION',
     11X,'VALUE PER UNIT CHANGE',/,6X,'IN RIGHT HAND SIDE',
     21X,'CONSTRAINTS.',2(/),1X,'PENALTY COSTS ARE CHANGE'.
     31X,'IN OBJECTIVE FUNCTION VALUE PER UNIT',/,6X,
     4'INCREASE IN NON-BASIC VARIABLES.',2(/),1X,
     5'RANGES ON C(J) REPRESENT LIMITING VALUES CF COST',
     61X,'COEFFICIENTS THAT',/,6X,'WILL MT CHANGE THE OPTIMUM',
     71X,'SOLUTION',2(//),2X,'RANGES CN B(I) REPRESENT LIMITING',
     81X,'VALUES OF RIGHT HAND SIDE CONSTRAINTS',/,6X,'THAT WILL',
     91X,'NIT CHANGE OPTIMUM BASIC VARIABLES.',2(/))
      RETURN
      END
      SUBROUTINE CHECK(K,NQUE,N,M)
      COMMON C(25),P(25),CMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
     1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
     2,B(25),CC(25),JVAR(25)
     3,IARR(4),PROP(4),RC(4),LD(4),SK(4),TK(4)
C
C*****THIS ROUTINE CHECKS TO SEE IF THE INDEX OF X(L) MATCHES THE
C     INDEX OF ANY OF THE OPTIMUM BASIC VARIABLES.  IF THERE
c     IS A MATCH, NQUE IS SET TO 1, OTHERWISE A VALUE OF ZERO IS
C     RETURNED.
c
      L=JVAR(K)
      NQUE=0
      DO 10 I=1,M
      KV=IVAR(I)
      IF(L-KV) 10,20,10
   20 NQUE=1
   10 CONTINUE
      RETURN
      END
      SUBROUTINE CNONB(K,N,M)
C
C*****THIS ROUTINE DETERMINES THE LOWER LIMIT FOR NONBASIC C(J).
c     M METHOD USED IS m FIND THE MINIMUM VALUE CF C(J) SUCH THAT
C     CBAR(J) IN THE OPTIMUM TABLEAU REMAINS NEGATIVE, THUS MAINTAINING
C     OPTIMALITY OF THE CURRENT SOLUTION.
C
      COMMON C(25),P(25),CMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
     1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
     2,B(25),CC(25),JVAR(25)
     3,IARR(4),PROP(4),RC(4),LD(4),SK(4),TK(4)
      J=1
      ZZ=0.
   10 KV=IVAR(J)
      ZZ=ZZ+CC(KV)*A(J,K)
      J=J+1
      IF(J.GT.M) GO m 20
      GO TO 10
   20 CL(K)=ZZ
      CU(K)=999999.
C
C*****INCLUDED IN THIS ROUTINE IS THE IDENTIFYING OF THE PENALTY
C     COST OF THE NONBASIC VARIABLES.  IT SHOULD BE
C     NOTED THAT IF THE PENALTY COST OF ANY NONBASIC X(J) IS ZERO,
C     THE PROBLEM HAS AN ALTERNATIVE OPTIMUM SOLUTION USING X(J).
c
      PCOST(K)=CMZ(K)
      RETURN
      END
      SUBROUTINE CBAS(K,N,M)
C
C     THIS SUBROUTINE DETERMINES THE RANGE ON OPTIMAL BASIC C(J)
C
      DIMENSION ZS(60)
      COMMON C(25),P(25),CMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
     1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
     2,B(25),CC(25),JVAR(25)
     3,IARR(4),PROP(4),RC(4),LD(4),SK(4),TK(4)
C
C*****FIRST, A MAXIMUM LIMIT IS SET ON THE UPPER AND LOWER BOUND
C     FOR C(J).  IF THE FINAL RESULT IN THE OUTPUT IS THIS
C     MAXIMUM VALUE IT CAN BE ASSUMED THAT M LIMIT DOES NOT EXISt.
C
      CUP(K)=999999.
      CLO(K)=-999999.
c
C*****THE LIMITS ON BASIC C(J) ARE DETERMINED BY THE VALUES CF THE
C     NONBASIC C(J)'S. EACH NONBASIC C(J) I S TREATED SEPARATELY, AND
C     A LIMIT ON C(J) IS DETERMINED BY FINDING THE MAX OR MIN VALUE
c     C(J) MAY HAVE IN ORDER m MAINTAIN THAT CBAR(J) NEGATIVE.
C
      J=0
   10 J=J+1
      IF(J.GT.N) GO m 75
C
C*****ZS(J) IS THE VALUE OF THE SUM OF THE INNER PRODUCTS OF CB AND
C     ABAR, EXCLUDING THE TERM INVOLVING THE BASIC C(J).
C
      ZS(J)=0.
      I=0
   15 I=I+1
      IF(I.GT.M) GO m 20
      IF(JVAR(J).EQ.IVAR(I)) GO m 10
      GO m 15
   20 L=0
   22 L=L+1
   25 IF(L.GT.M) GO m 30
      LV=IVAR(L)
      IF(LV.EQ.JVAR(K)) GO m 35
      ZS(J)=ZS(J)+CC(LV)*A(L,J)
      GO TO 22
   35 NI=L
      GO TO 22
C
C*****IF A(NI,J) IS SMALL, IT IS IGNORED BECAUSE IT APPEARS IN THE
c     DENOMINATOR. OTHERWISE, IF IT IS POSITIVE, A LOWER LIMIT IS
C     FOUND, AND IF IT IS NEGATIVE, AN UPPER LIMIT IS FOUND. THESE
c     VALUES ARE MN COMPARED m THE PRESENT LIMITS.  IF THEY ARE MORE
C     RESTRICTIVE THAN THE PRESENT LIMITS, THE PRESENT LIMITS ARE
C     REVISED.
C
   30 IF(ABS(A(NI,J)).LT.1.E-08) GO m 10
      IF(A(NI,J)) 40,10,50
   40 TCU= (C(J)-ZS(J))/A(NI,J)
      IF(TCU.LT.CUP(K)) CUP(K)=TCU
      GO m lo
   50 TCL=  (C(J)-ZS(J))/A(NI,J)
      IF(TCL.GT.CLO(K)) CLO(K)=TCL
      GO m lo
   75 CONTINUE
      RETURN
      END
      SUBROUTINE BRANG(N,M)
C
C*****THIS ROUTINE DETERMINES THE RANGES ON AL B(I).
C
      DIMENSION PPRIME(40)
      COMMON C(25),P(25),CMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
     1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
     2,B(25),CC(25),JVAR(25)
     3,IARR(4),PROP(4),RC(4),LD(4),SK(4),TK(4)
      K=0
   30 K=K+1
      IF(K.GT.M)GO m 36
C
C*****INITIAL UPPER AND LOWER BOUNDS ON B(K) ARE SET.
C
      BUP(K)=999999.
      BLO(K)=-999999.
      I=0
   20 I=I+1
      IF(I.GT.M) GO m 30
C
C*****PPRIME IS THE VALUE OF THE SUM OF THE INNER PRODUCT B-INVERSE
C     TIMES B(I), EXCLUDING THE TERM INVOLVING THE B(K) WE ARE FINDING
C     LIMITS FOR.
C
      PPRIME(I)=0.
      J=0
   10 J=J+1
      IF(J.GT.M) GO m 25
      IF(J.EQ.K)GO m 15
      PPRIME(I)=PPRIME(I)+A(I,J)*B(J)
      GO TO 10
   15 NI=J
      GO TO 10
C
C*****IF A(I,NI) IS SMALL, IT IS IGNORED. PRESENT LIMITS ARE THEN
C     REVISED IF IMPROVEMENTS ME POSSIBLR.
C
   25 IF(ABS(A(I,NI)).LT.1.E-8) GO TO 20
      IF(A(I,NI)) 26,20,27
   26 TBU=-PPRIME(I)/A(I,NI)
      IF(TBU.LT.BUP(K)) BUP(K)=TBU
      GO TO 20
   27 TBL=-PPRIME(I)/A(I,NI)
      IF(TBL.GT.BLO(K)) BLO(K)=TBL
      GO TO 20
   33 RETURN
      END
/GO

data cards go here

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Koger, Jerry L. and Webster, Dennis B. 1984. L-O-S-?‘: Logging Optimization Selection Technique. U. S. Dept. of Agric. For. Serv. Res. Pap. SO-203, 66 p. South. For. Exp. Stn. New Orleans, La.

L-O-S-T is a FORTRAN computer program developed to systematically quantify, analyze, and improve user selected harvesting methods. Harvesting times and costs are computed for road construction, landing construction, system move between landings, skidding, and trucking. A linear programming formulation utilizing the relationships among marginal analysis, isoquants, and the harvesting methods is used to estimate and select the harvesting procedure having maximum profits.

Additional keywords: optimization, harvesting, computer program, roadbuilding, skidders, hauling.

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