AN ABSTRACT OF THE THESIS OF

JON KEITH SCHNARE for the degree of MASTER OF SCIENCE

in FOREST ENGINEERING presented on MARCH 9, 1978

Title: FACTORS THAT AFFECT U.S.D.A. TIMBER SALE LAYOUT TIME IN THE PACIFIC NORTHWEST

Abstract approved: Dennis P. Dykstra

Dennis P. Dykstra

The change in emphasis from tractor and highlead logging systems to the advanced logging systems of skyline, balloon and helicopter has stirred researchers to study the operations of the advanced systems. The extra work involved in preparing an area for contract timber removal using advanced logging systems, however, has not been studied. The impacts of the extra time and extra manpower required for this process are large and they are important impacts which need to be taken into consideration during crew work planning. This is difficult to do since the factors which affect crew manhours have not been defined.

The objectives of this paper are to determine which factors affect the number of manhours spent on the presale fieldwork portion of preparing a U.S.D.A. Forest Service timber sale for contract; to compare presale field work time on conventional and special-design sales; and to develop a methodology for predicting presale fieldwork time.

Previous studies suggest some factors which affect forestry work, but the quantitative changes in production caused by each factor have not been measured. Logging operations research and human engineering studies report that the following factors affect production: underbrush, topography, weather, heat, cold, muscle fatigue, motivation, the work-

rest period, tobacco, and alcohol. Motivation is often an overriding factor which outweighs all other considerations. Motivation was not measured in this study, but it was expected to have some effect on the results. Topography, underbrush, and weather were expected to be the most important variables for predicting manhours.

Data or presale fieldwork time were collected from 16 districts on eight National Forests in Oregon and Washington, using a form designed to simplify data collection and coding for computer input. The form was a daily work record which could be easily filled out in a few minutes by the field crew.

District personnel on each of the 16 districts were personally contacted about cooperating in the study, but they were not pressured to collect data even if they agreed to cooperate.

The sample was designed to collect a distribution of data from the coast, eastside, and Cascade areas respectively, but most data collected came from the Cascade area.

Activity categories for data collection included layout, traverse, marking,cruising, skyline profile, wildlife related activity, land line retracement, spur road traverse, spur road location, and timber stand examination. The data were separated by activity and by complete units, and were analyzed using a stepwise multiple regression program.

Variables found to increase the number of manhours required for presale fieldwork were acres, boundary sinuosity, and silvicultural treatment. The significant variables which reduced manhours were landscape management designation and the distance walked from the vehicle to the unit. These two variables had been expected to increase manhours, but the effect of motivation may have been the cause for the unexpected reverse of sign on the regression coefficients. Special design designation showed no significant effect on manhours except through boundary sinuosity.

The regression equations recommended for use in predicting manhours are for the activities of layout using on-the-ground aerial photo-

interpretation; traverse using a hand compass, clinometer, and chain; marking of leave trees; cruising by the variable plot method; and for the Cascade area complete units. Nomographs are provided for the solution of these regression equations.

Factors That Affect U.S.D.A. Timber Sale Layout Time in the Pacific Northwest

by

Jon Keith Schnare

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed March, 1978

Commencement June, 1978

APPROVED:

Dennis P. Dykstra

Assistant Professor of Forest Engineering
in charge of major

George W Brown

Head of Department - Forest Engineering

Dean of Graduate School

Date thesis is presented March 9, 1978

Typed by Maja Laird and Laurel Smouse for Jon Keith Schnare

ACKNOWLEDGEMENTS

My sincere thanks to the men in green, the presale foresters and technicians of the U.S. Forest Service who collected data for me. I appreciate your hard work and willing cooperation. I wish to express my gratitude to D.P. Dykstra, my major professor, who kept me on the path with his guidance and inspiration. A special thank you and all my love to my wife Bonnie who persevered.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Factors That Affect U.S.D.A. Timber Sale Layout Time in the Pacific Northwest

INTRODUCTION

The advance of the logger into the forest has assumed the pattern of the U.S. Marine Corps taking an island during World War II. The objective is to produce logs. Therefore the more difficult areas to log are bypassed until they cannot be avoided.

These tough logging shows call for more sophisticated logging methods, and skyline, balloon, and helicopter systems have appeared to fill this need. This has led to timber sale appraisal problems. The U.S.D.A. Forest Service bases its appraisal system on experienced costs collected from logging companies. For the advanced logging systems, there were no experienced costs. This prompted a flurry of activity in research to study the advanced logging systems and to produce a formula by which a cost appraisal could be made for each system.

With all of this concern for equipment and logging costs, the extra cost of designing sales for these systems was forgotten. The people on the ground doing the work felt the impact of the extra time and skills that were needed, but no effort was made to find out what affected the man in the field or to help him plan and cost out his work load. As a result, some of the field work did not get done and problems developed as units were logged. The district personnel saw the need for more money and manpower to accomplish the increased work load, but had very little information on which to base this need. The factors which increased the time spent in the field were still undefined.

This study attempts to find these factors, and to put them into a usable form to predict manhours and thereby costs and personnel needs.

STUDY OBJECTIVES

1. Determine the factors which affect manhours spent on the presale fieldwork portion of preparing a U.S.D.A. Forest Service timber sale for contract.
2. Compare presale manhours spent on regular timber sales to presale manhours spent on special design timber sales.

3. Develop a method of predicting manhours needed to do the presale fieldwork on regular or special timber sales.

LITERATURE REVIEW

Previous studies of logging and forestry work have concentrated on the factors involved in the operation of making trees into logs and transporting the logs to the landing and to the mill (Aulerich et al. 1974, Binkley 1965, Campbell 1972, Dykstra 1975, Dykstra 1976, Peters 1973, Sinner 1973). No studies were found that addressed the factors involved in preparing an area to be logged. Several articles were found which touched on presale or prelogging layout and design, but they were lacking in detail about the time required to do the job, or they simply specified the job to be done (Binkley and Lysons 1968, McGonagill 1973 and 1975). Even the U.S.D.A. Forest Service does not presently have guidelines on how long it should take to accomplish the job of timber sale design and layout (Frederick 1978). Minimum standards of quality have been written for each task, but the length of time to do the task is left up to the district personnel to ponder. This works well as long as a totally new situation does not arise for which there is no past experience.

Binkley and Lysons (1968) have published a detailed procedure for planning skyline sales which is a good blueprint for most sale layout. The specific parts of design and field work are addressed so that the amount of work involved can be identified, but no idea is given as to the length of time needed to do the work.

McGonagill (1975) states that planning tools such as critical path or PERT should be used to plan field work to insure completion in a timely manner. However, he does not address the factors which affect the amount of time needed to lay out a timber sale.

Conway (1976) addresses the factors which affect logging operations and some of these factors can be used to look at the presale operations. The factors that affect manpower operation are: volume per stem, underbrush, topography, and weather. Volume per stem affects the number of trees involved and can affect marking and cruising, although Conway is more interested in the effect on falling production. Underbrush affects the worker's progress through the woods no matter what his job. Topography has a similar effect on the worker, with steep ground being more critical than gentle or rolling ground. Weather has a subtle impact on operations, and changes by region. The weather effect varies from simply lowering productivity to totally stopping operations.

Conway's discussion of these factors is in general terms only, and he mentions little information as to what planning adjustments to make in accounting for them.

A review of human functioning under work or stress conditions was undertaken to see what influences the function of the human body and to relate this information to field conditions. Several of the studies were on workers in forestry operations and should be pertinent to the subject of this study.

Age, motivation, state of training, water balance, deposits of available energy, mental stimulation, heat, and cold are important for human performance capacity (Astrand and Rodahl 1970, McCormick 1970).

Heat and cold acclimatization deals with the effect of weather conditions on the human body and its ability to function. Acclimatization to heat occurs in four to seven days and is reasonably complete in 12 to 14 successive days of exposure to heat (Astrand and Rodahl 1970). Heat is shown to reduce performance of physical work activities. The hot end of the temperature scale is more important to the physical well-being since man can protect himself from cold more easily than from overheating. Fatigue and alcohol consumption impair the heat acclimatization effect (McCormick 1970).

Associated with heat is thirst and the water balance. The cessation of thirst is not an adequate indicator of water needs and underestimates the need to replenish water loss during periods of heavy perspiration. This is important since an individual tolerates heavy physical work less well with a water deficit even if it is only one percent of the body weight (McCormick 1970).

Acclimatization to cold conditions takes months or years, and full acclimatization is usually never achieved (Astrand and Rodahl 1970, McCormick 1970). Local acclimatization of body parts may occur such as increased bloodflow to hands or feet (McCormick 1970). For cold weather, know-how and experience are more important than acclimatization.

The human factor reaction to cold is increased numbness and increased reaction time which affects finger dexterity and body movement. This causes increased time to accomplish most measurement activities or movement from one place to another after chilling during stationary activity. Mental performance is not necessarily affected by cold (Astrand and Rodahl 1970).

Muscle metabolism appears to be a controlling factor for heart and respiration rates. The physiological price of work per unit of work is greater at higher rates of work than at moderate rates: climbing hills fast is more costly to the body than climbing hills slowly (Astrand Rodahl 1970). If a muscle works at a rate at which adequate oxygen is supplied by the lungs and heart, then little or no lactic acid accumulates. As the demand for oxygen increases and cannot be supplied, the anaerobic process supplies energy to the muscle, the lactic acid waste builds up, and the muscle slows and eventually stops. This muscle fatigue is reversible with rest and mild exercise and it is found that light exercise with other muscle groups than those fatigued can promote recovery (McCormick 1970, Vik 1971).

Leg muscles take more oxygen than arm muscles due to the size of the muscles, so that after climbing a hill, use of the arms in measuring trees or tacking boundary tags may lessen leg fatigue faster than sitting and resting.

Forest workers were found to have greater aerobic capacity than other workers tested (Van Loon and Spoelstra 1971). This implies that forest workers work in a stress situation which has developed this extra capacity, since no difference in physical build was found.

Mechanical efficiency for such activities as running or walking is very slightly increased with training (McCormick 1970). The surface on which the walking is done does have an effect. Rough surfaces take more energy than smooth surfaces and the energy expense is considerably higher for walking on steep grades than walking on level ground. Going downhill only involves one-third the energy of going uphill (McCormick 1970).

Motivation is a controlling factor in how far a fatigued muscle can be made to operate in the fatigued state. High motivation works the muscles well past the point of stiffness or point at which muscles seem to want to stop obeying the command to work. The feeling of fatigue is different for each person, but in the study cited (McCormick 1970) motivation was effective on all the healthy subjects.

The strenuous work period has a great deal to do with the length of time that a human being can continue to work effectively. The average man has 2500 calories available as energy reserve (Astrand and Rodahl 1970). Rest is necessary to replenish this reserve if work is to continue. Blood supply and oxygen store also need rest periods to be most effective. The contraction of muscles inhibits the flow of blood with oxygen and energy rich compounds. This causes more use of the anaerobic cycle and more waste build up. The rest period allows a shift from anaerobic to aerobic oxygen with less build up of wastes, and allows the blood stream to cleanse the muscle for renewed effort (McCormick 1970).

The work-rest cycle is particularly important to older workers. It allows them to maintain high performance for short periods of time. By allowing the older worker to pace himself, the effect of less efficient body functions due to age can be overcome and his effectiveness in field work will be prolonged (McCormick 1970, Astrand and Rodahl 1970). This should also be true for the worker who is not in good condition because he has been sitting in the office all winter.

Tobacco smoking was found to have a dramatic effect on respiratory and circulatory systems. The inhalation of smoke within seconds causes a two to three fold increase in airway resistance, which could be important during heavy work periods. The effect on the circulatory system is due to the fact that carbon monoxide has 200 to 300 times more affinity for the red blood cell than oxygen and causes a 5 to 10 percent oxygen capacity blockage. Since training or conditioning only increases oxygen uptake by 10 to 20 percent, a 5 to 10 percent reduction for smoking is significant during heavy work. The effect on heart rate was not noted if a rest period of 10 to 45 minutes occurred before work resumed (McCormick 1970).

From these studies several management practices are suggested where it is not possible to modify the extreme environmental conditions as occurs in forestry work: (1) select personnel who can tolerate the conditions, (2) permit people to gradually acclimate, (3) establish an appropriate work-rest schedule, (4) rotate personnel on the heaviest tasks, (5) modify work hours to work cool parts of the day in hot weather, (6) maintain water balance in hot weather (Astrand and Rodahl 1970).

Summary

From an experience standpoint, Conway (1976) found that underbrush, topography and weather influence crew production. Human engineering studies show that heat,cold,muscle fatigue,motivation,the work-rest period,tobacco and alcohol affect the ability of a human to produce. Tying this information together shows a relationship of work,weather,heat, cold,underbrush, and topography as muscle fatiguing factors balanced by the muscle recovery factors of rest,conditioning,and proper water balance.

Topography appears to a major muscle fatigue factor. Add to this underbrush, poor footing due to wet or slick ground conditions, and heat with loss of water or cold with its numbing effect, and the time to complete a task could lengthen. Whether these factors are additive or multiplicative is not apparent from the studies.

The work-rest cycle and motivation may be as important as topography and its related factors. Both work-rest and motivation are hard to measure, and either factor could have enough influence on production to nullify any results from a topography viewpoint.

Some tasks, such as cruising and traversing, have a work-rest cycle built into them. The method of accomplishing each task could give an indication of the work-rest cycle, but not of the speed at which it is repeated.

Motivation, such as working faster to finish a project so that it does not have to be visited again, cannot be measured. Motivation is an important factor, but since there is no good way of measuring it and comparing one crew's motivation to another's, it will be disregarded in this study.

The physical condition of the crew will improve as time into the field season increases. This should increase production, especially with temporary crews. The conditioning effect could be nullified by the negative motivation of job boredom, and again the results would be confused. Crew conditioning has not been measured in this study and will be disregarded.

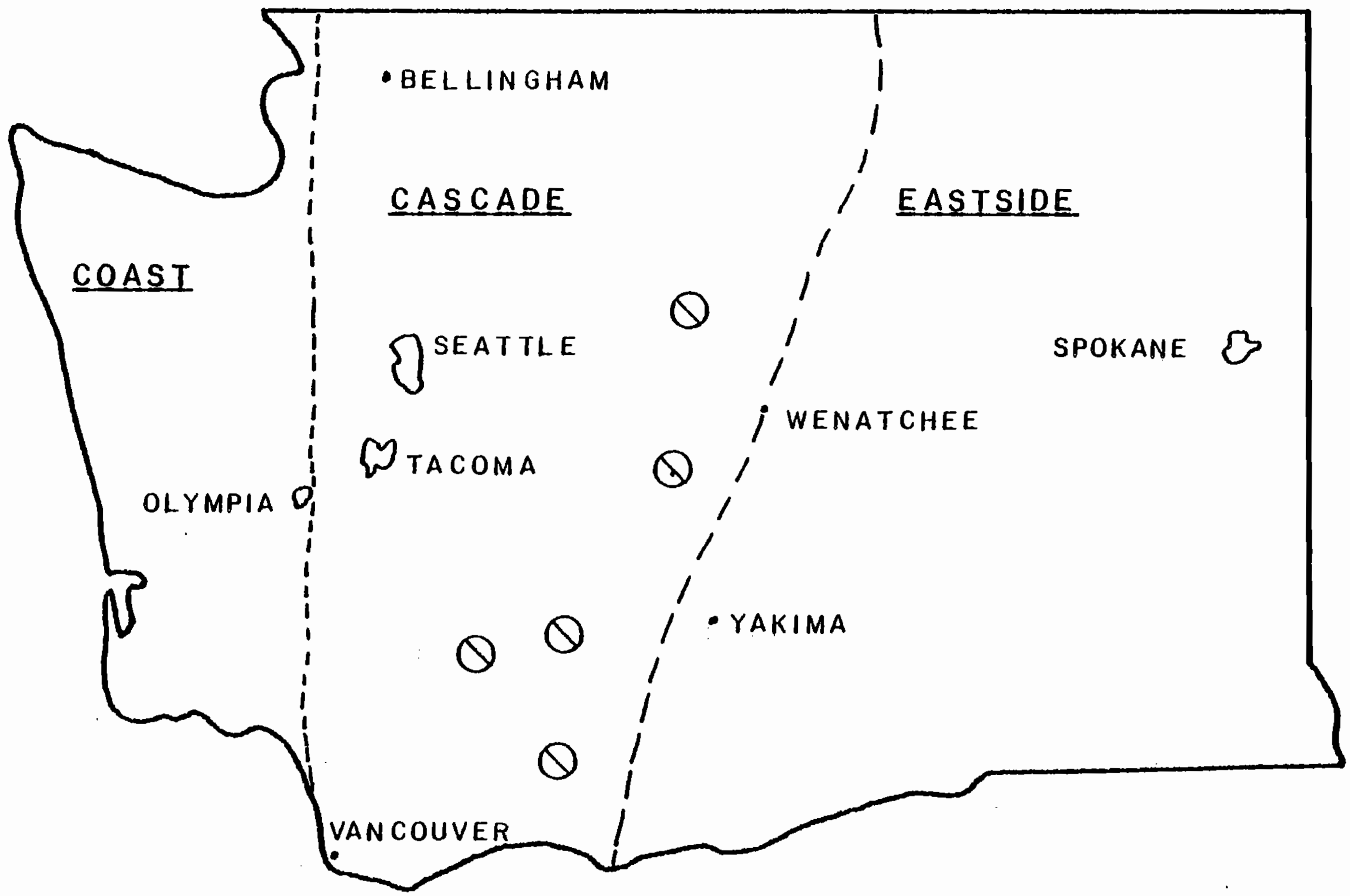
SCOPE

Data collected for this study were obtained from ongoing timber sales in preparation on sixteen districts of eight national forests in Washington (Fig. 1) and Oregon (Fig. 2).

The data collection was designed to represent a cross-section of the large timber sale types found in the Pacific Northwest, with an expected mix of data of 25 percent each from the coast and eastside areas, and 50 percent from the Cascade area. However, due to large sales on the eastside area, only parts of two units were started and finished in the collection period from districts collecting data. The coast area is represented by 5.9 percent of the data and 94.1 percent of the data is from the Cascade area.

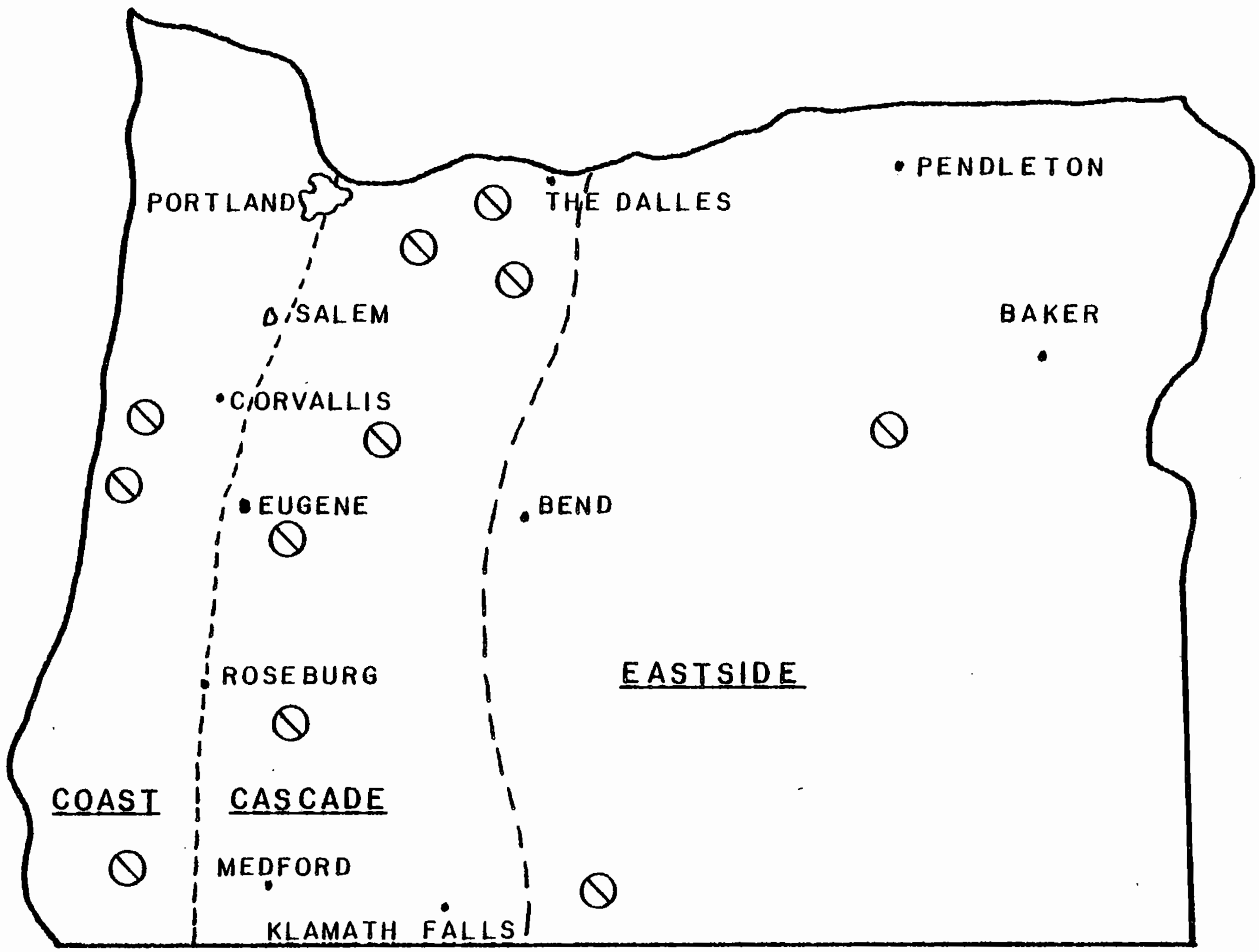
Only the field portion of timber sale preparation is included in this study due to the difficulty of separating office time by sale and unit.

The field season for data collection ran from August 1972 through early January 1973 on the Pansy Basin units of the Estacada Ranger District, and from July 1977 through October 1977 for all other data.



DATA COLLECTION SITES IN THE STATE OF WASHINGTON

FIGURE I.



DATA COLLECTION SITES IN THE STATE OF OREGON

FIGURE 2.

Weather ranged from clear and sunny to overcast and snowing for both sets of data.

The proposed logging systems for the sales include a wide range of the common and advanced systems presently in use in the Pacific Northwest. These include ground skidder systems, highlead, skyline, and multispan skyline cable systems, balloon cable systems, and helicopter aerial systems.

The data were divided into the following activity categories.

1. Layout: four methods were cited for the task of reconnaisance, locating and marking the unit boundaries on the ground.
2. Traverse: two methods were used to traverse the unit boundaries. Only one involved field measurements and only this method is analyzed.
3. Marking: either leave trees or take trees were designated in the partial cut units. Both methods were analyzed.
4. Cruising: four methods were used to determine the volume of timber in the units.
5. Skyline profile: only one method was reported for running skyline profiles, although several methods are commonly used throughout the Pacific Northwest.
6. Wildlife related activity: this activity includes providing future and present housing for birds and small mammals, and locating species that are on the endangered list for protection of habitat.
7. Land line retracement: two methods were used to retrace or re-establish land lines and corner monuments. Only one method could be tied back to specific units and therefore it was the only one used in the study.
8. Spur road traverse: only one method was reported for this activity.
9. Spur road location: only one method was reported for this activity.
10. Timber stand examination: only one method was reported for stand exams and too few were reported for proper analysis.

METHOD OF DATA COLLECTION

This study was designed to collect data from the whole spectrum of national forests in Washington and Oregon. A ¼, ¼, ½ mix of data was attempted from the coast, eastside, and Cascade timber types, respectively. To accomplish this, forest logging specialists were contacted to ascertain which districts on their forest would have enough work load to make data collection worthwhile. A mix of sales by proposed logging systems was also a criteria.

To keep balance and broadness in the study, no more than three districts were selected from any one forest. The presale forester or timber management assistant was personally contacted about collecting data for the study, and if he was agreeable, the district was added to the sample list. In all 30 districts were picked to be sampled. A packet of forms, instructions, and a letter to the District Ranger explaining the reason for the study and the low time impact to his personnel were sent out to each study district. The District Ranger still had the perogative to cancel the study on his district, and one did so.

After issuance of the forms, questions were answered if districts had problems, but no other contact was made until time to collect the completed forms in late October, 1977.

The sample size of 30 districts was determined by use of the formula for the error of estimation:

$$E = Z * \frac{T}{\sqrt{n}}, \text{ which can be rearranged to } n = \left(Z * \frac{T}{E}\right)^2,$$

where n = the sample size, Z = the indicator of confidence or the probability level, T = the measure of dispersion in the original population, and E = the maximum amount of difference allowable between the point estimate and the true value (Ingram 1974). The Pansy Basin data were analyzed to find values of T and E for use in the formula.

The value of Z was picked for a 95 percent confidence interval. The computed value of n for complete units showed that 121 units needed to be sampled.

$Z = 1.96$ (95%)

$T = 42$ hrs

$E = 7.5$ hrs (one net working day)

$$n = \left(\frac{1.96 * 42}{7.5}\right)^2 = 120.5$$

use 121

Three hundred to six hundred units were assumed to be sampled if all 30 districts collected data, but some downfall was expected. Not all units would be started or finished within the collection period. This meant that more districts were needed to insure enough data for a good distribution.

Approximately one-half of the districts that agreed to collect data dropped out of the study for various reasons. This left a smaller sample, but it was still larger than the planned minimum of 121 units.

The data form, shown in Appendix I, was designed to take very little time or effort to complete. The heading specified details of the unit: name, number, area, trees per acre,average slope,type of cut,and any special design considerations. All of this data is needed for sale records and appraisal so that there was no extra impact on the district to collect it.

The body of the form is a daily record of work on the sale unit and the conditions encountered during the work period. Filling out this part of the form takes 30 seconds to 1 minute per day.

The activity method description provides for coding and describing the work method for each task. This coding was used to separate the data for analysis.

The data collection was designed to collect the type of information from an area which could be predicted from maps, aerial photos, quick reconnaissance, and past weather records.

A guide and coding form was provided at the bottom of each data sheet to standardize responses from the districts. Each unit data sheet requested that a topographic map of the unit area be submitted with the unit plotted on it. The purpose of this was back-up for average slope data, and for coding the unit boundary shape.

DESCRIPTION OF ACTIVITIES

Data were collected for the following activities and methods of accomplishing the task.

1. Layout: Four methods were reported for the process of reconnaissance, locating, and marking a unit boundary on the ground.

   Method 1: On-the-ground photo-interpretation was used to transfer planned units on maps and photos to the ground location.

   Method 2: Unit boundaries were offset at right angles from a surveyed skyline profile using a cloth tape to measure distances.

   Method 3: An office-plotted unit boundary was located on the ground by running a Redi mapper in reverse. A Redi mapper is a hand held plane table which uses a hand compass for the alidade.

   Method 4: An office-plotted unit boundary was located on the ground by surveying methods using a compass and steel chain or cloth tape.

2. Traverse: Two methods were reported for the process of measuring the acreage of the unit. Only the field method was able to be tied to specific units and analyzed.

   Method 1: A hand compass, clinometer, and engineers' tape or two-chain trailer tape were used to measure angles, slopes and lengths of the unit boundary, from which acreage was calculated.

   Method 2: Units bounded by well-defined features on aerial photographs had the area measurement taken directly from the photograph by photogrammetric methods. Only one datum was cited for this method.

3. Marking: Two methods were reported for the process of designating trees with paint.

   Method 1: Leave trees were marked with paint sprayed from a hand pumped paint gun. Trees were painted at 4-5 feet up from the base and at the base.

   Method 2: Take trees were marked with paint sprayed from a hand pumped paint gun. Trees were painted at 4-5 feet up from the base and at the base.

4. Cruising: Four methods were reported for the process of obtaining a statistically correct sample of volume for each unit.

Method 1: 1/5 acre plots were cruised on a predetermined grid base.

Method 2: Variable plots were cruised on a grid basis. Several different basal area factor prisms or a Relaskop were used.

Method 3: The 3P method or 100% cruise method were used in conjunction with marking trees.

Method 4: A percentage cruise using random sampling procedures was used in conjunction with marking trees.

5. Skyline profile: One method was reported for measuring the ground profile of a proposed skyline. A hand compass, engineers tape, and clinometer were used to measure azimuth, distance and slope from break to break.

6. Wildlife related activity: Two methods were reported for this activity.

Method 1: Nailing wildlife reserved tree markers on 2-4 trees per acre throughout the unit.

Method 2: Locating endangered species of birds by response to a tape recorded bird call. This activity took place within the unit or near vicinity.

7. Land line retracement: Two methods were reported, but only one was analyzed because only one method could be tied back to individual units.

Method 1: Existing corner monuments were located, and the line between corners was reestablished with a staff compass. This line was flagged.

Method 2: A Wilde T2 theodolite, steel chain, and standard high class surveying procedures were used to reestablish land lines and missing survey corner monuments. This method was not analyzed.

8. Spur road traverse: One method was reported for this activity. A hand compass, clinometer, and engineers' tape were used to measure angles, side slopes, grades, and distances of the preliminary line for the proposed roadway.

9. Spur road location: One method was reported for this activity. Aerial photo-interpretation, clinometer, and pacing were used to flag control points and mark the location line for the survey crew.
10. Timber stand examination: One method was reported for this activity, but the sample was too small to analyze.

The individual activity data were compiled for units which had a complete set of activities, so that a multiple regression could be run on the unit data.

Cascade, coast, and all sale data were compiled. The purpose of this was to form a comparison between Cascade and Coast Range data, to see if there were any basic differences.

METHOD OF MULTIPLE REGRESSION ANALYSIS

The stepwise regression analysis program of the statistical interactive programming system (SIPS) was used on Oregon State University's CDC-3300 computer to analyze all data.

SIPS stepwise program uses the largest partial correlation value to pick the best variable to enter at each step of the analysis. This variable should give the greatest reduction of residual variability below that of the current model. The mean,beta values,analysis of variance (ANOVA), the standard error of regression for all variables in the present model, t value or ratio of the regression coefficient with its standard error for each variable in the present model, and the coefficient of determination (R^2), are calculated at each step of the analysis.

The procedure used to determine the model to be used was done by hand since SIPS does not check variables that are in the model for continued relevance. The procedure is as follows:

1. Check the F statistic of the last variable to enter the model, by the formula:

$$F = \frac{SSRp - SSR_F}{MSR_F},$$

where SSRp is the residual sum of squares for the partial model, SSR_F is the residual sum of squares for the full model, and MSR_F is the residual mean sum of squares for the full model. Degrees of freedom used to test the F value are 1 for the entering variable and the degrees of freedom for residual in the full model. A .1 significance level was used for the F statistic.

2. The t ratio of each variable was checked for significance to assure that it was still significant after the addition of the new variable. A value of 1.376 or .20 probability level was the cut-off value for the old and new variables. The previous model was then chosen or a new model fitted dropping the insignificant variable.

3. The best multiple regression equation was picked from the equations that had a high R^2 value and a minimum number of variables. If a choice had to be made between an equation using a variable formed by manipulation of the measured variables and an equation only using measured variables, the equation only using measured variables was selected.

MULTIPLE REGRESSION ANALYSIS

The purpose of this study is to determine the factors which affect manhours spent on pre-sale field preparation of USDA timber sale, and to develop a method of predicting the manhours required to do this work on a proposed sale. The multiple regression analysis should accomplish both the purposes. Since little is known about future sale areas in unlogged country except what can be found on topographic maps, aerial photographs, extensive reconnaissance, timber stand maps, and weather records, this information must be the basis for time requirement estimates. The variables measured in this study can be found in the general information base.

In the regression summaries which follow,
*** indicates that the regression coefficient for the independent variable is significantly different from zero at the 0.01 probability level;
** indicates that the regression coefficient for the independent

variable is significantly different from zero at the 0.05 probability level but not at the 0.01 level;

* indicates that the regression coefficient for the independent variable is significantly different from zero at the 0.10 probability level but not at the 0.05 level;

R^2 is the coefficient of determination, a measure of the fraction of variance in the data explained by the regression equation;

n is the number of observations in the sample.

Mnemonics

Manhours -- The net manhours spent on an activity. These hours include all the field time except vehicle travel time to and from the project.

Acres -- The computed acres in each sale unit.

TPA -- The number of trees per acre as measured by the sale cruise.

Slope -- The average ground slope in percent for the unit, obtained from map measurements and field checked.

Walkin -- The one way distance walked to get from the vehicle or last unit to the unit being reported.

Cloud -- The presence of or absence of an overcast sky. Zero if the sky was clear and 1 if overcast.

Precip -- The presence and type of precipitation which occurred during the work activity. Zero if there was no precipitation; 1 if rain; 2 if snow; and 3 if sleet.

Temp -- The relative temperature regime of the work area. -1 if the air felt warm or cool; zero if hot; 1 if cold.

Grncond -- The relative footing or ground condition of the work area. -1 if the ground was dry; zero if wet; 1 if snow or ice covered.

Brscond -- The difficulty of walking through the brush on the work area. Zero if the brush was light and easy to walk through with few tripping hazards; 1 if moderate to easy walking with tripping hazards or obstructions up to one-half the time; 2 if heavy to moderate difficulty walking with constant tripping hazards or dense brush; 3 if extremely heavy to heavy difficulty walking, in essence no longer walking; instead climbing, swimming, or crawling through the brush.

Bndry -- The relative sinuosity of the unit boundary. This variable specifically defines units with boundary conditions designed for a specific purpose, usually landscape design. Zero if the unit had a normal boundary and 1 if the boundary was convoluted or sinuous.

Silvi -- The general silvicultural prescription for the unit. Zero if the prescription was a clearcut; 1 if shelterwood; 2 if overstory removal; 3 if equal spaced thinning or partial cut; and 4 if clumped thinning or partial cut.

Scape -- The landscape management designation for the unit. Zero if the designation was maximum modification; 1 if modification; 2 if partial retention; and 3 if retention.

Wildlife -- The designation for a unit with special wildlife considerations which must be taken into account during presale activities. -1 if the unit had no special considerations; zero if the unit had special designation, but not this designation; and 1 if the unit had this special designation.

Fisher -- The designation for a unit with special fishery considerations which must be taken into account during presale activities. -1 if the unit had no special considerations; zero if the unit had special designation, but not this designation; and 1 if the unit had this special designation.

Water -- The designation for a unit with special water quality considerations which must be taken into account during presale activities. -1 if the unit had no special considerations, zero if the unit had special designation but not this designation; and 1 if the unit had this special designation.

Soils -- The designation for a unit with special soil considerations which must be taken into account during presale activities. -1 if the unit had no special considerations; zero if the unit had a special designation, but not this designation; and 1 if the unit had this special designation.

Activity Multiple Regression

The data were compiled by activity for each unit. The data were compiled only if the unit's activity started and finished within the study period. This allowed for more data in the activity regressions than was used in the complete unit regressions since many districts reported partial unit completion.

Multiple Regression for the Layout Activity

This activity is represented by four methods of accomplishing the task. The significance of landscape and special design considerations should be of importance to each method, and the data for each method was regressed separately to show this significance.

Method 1

The data for method 1 are summarized in Table 1. All of the independent variables are represented by a range of values, and therefore all the independent variables are used in the regression analysis.

TPA and Precip were felt to be important factors for the time involved in locating one's ground position on the aerial photograph, but this did not prove true. The variable of the square root of Acres (Acsq) was calculated and added to the list of independent variables. This variable always entered the regression as a negative coefficient. It also caused several other entering variables to come in with the wrong sign. This did not happen when Acsq was left out of the regression equation, therefore Acsq was dropped from the regression due to lack of explanation for the phenomenon.

Table 1. Summary of Data for Layout--Method 1

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	264	480.0	0.3	8.35	1.849	902.37
ACRES	264	460.0	1.0	24.28	2.650	1,854.60
TPA	264	425.0	4.0	86.20	2.447	1,580.67
SLOPE	264	90.0	1.0	34.36	1.125	334.18
WALKIN	264	9,990.0	0.0	731.88	88.613	2,072,997.80
CLOUD	264	1.0	0.0	0.38	0.028	0.22
PRECIP	264	2.0	0.0	0.28	0.027	0.19
TEMP	264	1.0	-1.0	-0.61	0.040	0.42
GRN COND	264	1.0	-1.0	-0.54	0.033	0.28
BRS COND	264	3.0	0.0	1.09	0.053	0.75
BNDRY	264	1.0	0.0	0.31	0.030	0.24
SILVI	264	4.0	0.0	0.62	0.066	1.16
SCAPE	264	3.0	0.0	0.56	0.052	0.73
WILDLIFE	264	1.0	-1.0	-0.48	0.050	0.67
FISHER	264	1.0	-1.0	-0.63	0.036	0.34
WATER	264	1.0	-1.0	0.63	0.036	0.34
SOILS	264	0.0	-1.0	0.68	0.29	0.22

The best multiple regression equation thus obtained was the following:

$$\begin{aligned} \text{Manhours} = & -6.5809 & & R^2 = .494 \\ & + 0.48601\ (\text{Acres}) & *** & n = 264 \\ & + 6.2563\ (\text{Bndry}) & ** & \\ & + 0.0016494\ (\text{Walkin}) & * & \end{aligned}$$

The variables in the equation all show the proper sign and have logical and statistical significance. The equation is good for a wide range of situations as shown by Table 1, but it should not be used outside the range of Acres, Bndry, and Walkin shown by the data in Table 1. Acres, Bndry, and Walkin should be easily measured from sale planning maps for use in estimating the time involved to layout a specific unit. For a planning tool, values as specified in mnemonics can be entered into the equation above or into the graph in Figure 3.

Method 2

The data summarized in Table 2 shows a small sample size, with a wide range of data. All the independent variables were used in the regression analysis.

Grncond was felt to have extra importance for footing on steeper slopes since the layout man would be walking at right angles to the slope. Brush condition and steepness of slope was also seen as an interaction. Therefore three interaction variables were entered as follows: Slope times Grncond; Slope times Brscond; and Slope times Grncond times Precip. The regression equation was restricted to one variable due the small sample size. The best multiple regression equation obtained was the following:

$$\begin{aligned} \text{Manhours} = & \ 8.7693 & & R^2 = .864 \\ & + 1.8631\ (\text{Slope} * \text{Grncond} & & \\ & \quad * \text{Precip}) & ** & \end{aligned}$$

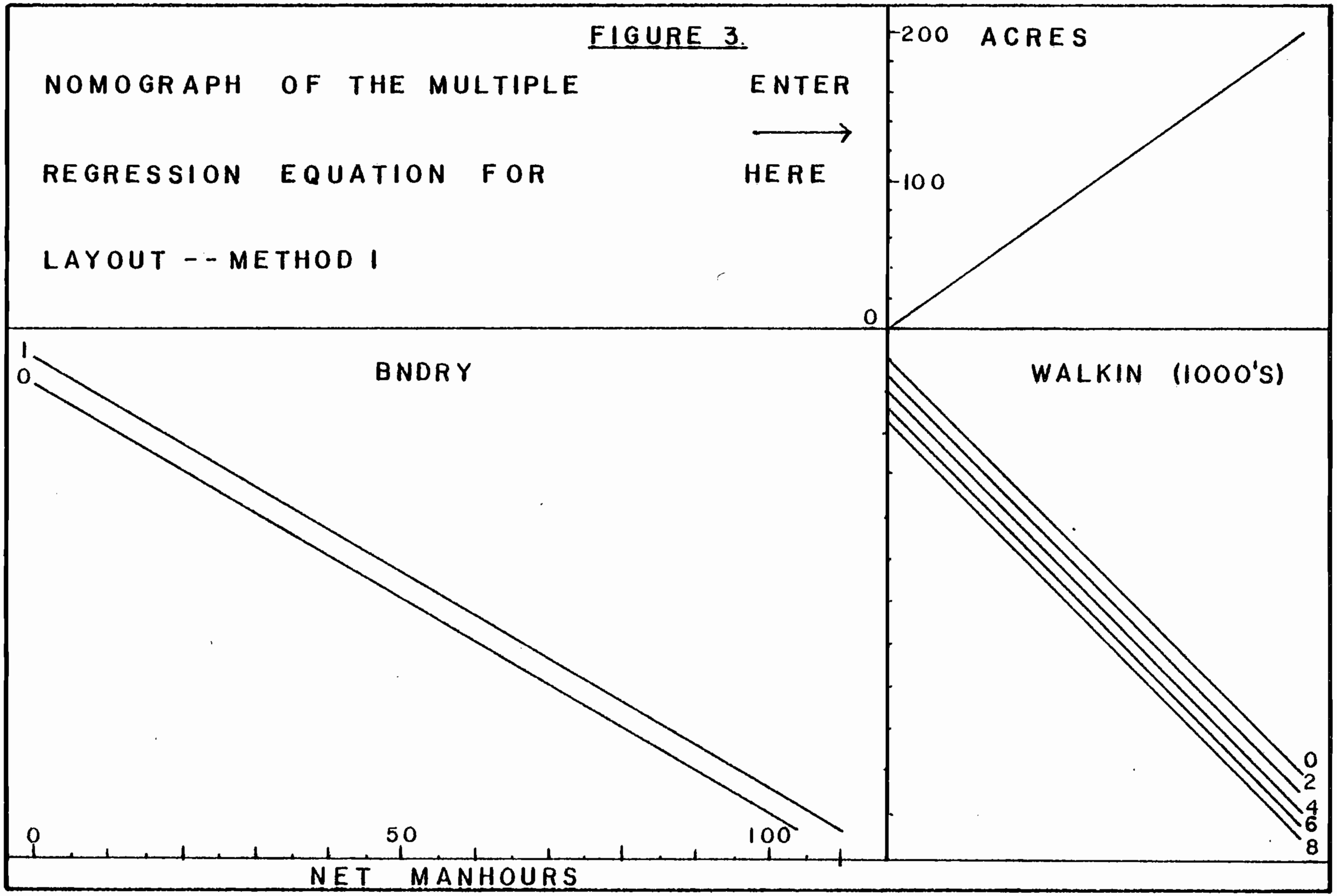


FIGURE 3.

NOMOGRAPH OF THE MULTIPLE REGRESSION EQUATION FOR LAYOUT -- METHOD I

Table 2. Summary of Data for Layout—Method 2

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MAN HOURS	5	88.6	6.0	30.40	14.918	1,112.80
ACRES	5	138.0	15.0	52.80	22.562	2,545.20
TPA	5	85.0	80.0	82.00	1.224	7.50
SLOPE	5	80.0	45.0	64.00	6.205	192.50
WALKIN	5	6,000.0	0.0	2,840.00	1,305.986	8,528,000.00
CLOUD	5	1.0	0.0	0.60	0.245	0.30
PRECIP	5	1.0	0.0	0.50	0.210	0.22
TEMP	5	1.0	-1.0	0.20	0.448	1.00
GRN COND	5	0.70	-1.0	-0.14	0.371	0.69
BRS COND	5	2.0	1.0	1.40	0.245	0.30
BNDRY	5	1.0	0.0	0.40	0.245	0.30
SILVI	5	3.0	0.0	0.60	0.600	1.80
SCAPE	5	2.0	0.0	1.0	0.316	0.50
WILDLIFE	5	1.0	-1.0	0.40	0.400	0.80
FISHER	5	0.0	-1.0	-0.20	0.200	0.20
WATER	5	1.0	-1.0	0.00	0.316	0.50
SOILS	5	0.0	-1.0	-0.20	0.200	0.20

This equation explains much of the data variance, but it should be noted that the slope data has a narrow range and that if either Precip or Grncond are zero, the variable becomes zero causing no adjustment to the mean value. This equation is not recommended for planning purposes.

Method 3

The data for method 3 show a small sample size and homogeneity of some data. The only two variables with any appreciable variance are Walkin and Brscond. Therefore, the following model was hypothesised:

$$\text{Manhours} = f(\text{Acres, Walkin, Brscond, TPA})$$

Acres should be important since method three uses a Redi mapper technique to lay a predetermined boundary on the ground. However, the range of acres is small to the point of being almost homogeneous, and its significance was reduced.

The regression equation was restricted to one variable by statistical significance. The best multiple regression equation obtained follows:

$$\text{Manhours} = 4.692 + 0.00087242\ (\text{Walkin})\ * \qquad R^2 = .316 \qquad n = 12$$

Brscond came in as the second variable, but it was not significant. This equation should be used with caution since it is based on a small sample of fairly homogeneous data.

Table 3. Summary of Data for Layout--Method 3

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	12	13.2	2.6	6.03	1.021	12.51
ACRES	12	10.0	6.0	8.83	0.441	2.33
TPA	12	113	113	113	0	0
SLOPE	12	25.0	5.0	15.83	1.353	21.97
WALKIN	12	8,500.0	300.0	1,537.5	658.428	5,202,329.54
CLOUD	12	0	0	0	0	0
PRECIP	12	0	0	0	0	0
TEMP	12	-1	-1	-1	0	0
GRN COND	12	-1	-1	-1	0	0
BRS COND	12	3.0	0.0	1.50	0.230	0.64
BNDRY	12	1	1	1	0	0
SILVI	12	0	0	0	0	0
SCAPE	12	1	1	1	0	0
WILDLIFE	12	1	1	1	0	0
FISHER	12	0	0	0	0	0
WATER	12	0	0	0	0	0
SOILS	12	0	0	0	0	0

Method 4

The procedure for method 4 is similar to method 3, but the data shown in Table 4 have more variance. The three homogeneous variables were left out of the regression analysis.

TPA and Brscond were hypothesized to be significant because they shorten the intervisible distance for taking compass bearings, but this could not be proved.

Only one variable came into the equation with statistical significance. The best multiple regression equation obtained follows:

$$\text{Manhours} = 6.0396 + 0.19389\ (\text{Acres})^{**} \qquad R^2 = .376 \quad n = 14$$

The second variable to enter the equation was Fisher, but it was not significant. It is nonetheless interesting that special design considerations might have some effect on this method of layout. It would have been nice to contrast method 3 and method 4 for this effect, but method 3 was homogeneous in special design variables.

Reviewing the four methods of layout shows several variables to be important. Each method has a different set of variables and there is no pattern to this series of regression equations until the equations for methods two and three are dropped. Acres then becomes the most prevalent variable. Acres should have been significant for method 3, since method 3 and 4 are similar. The narrow range of Acres in method 3 probably prevented its significance. Method 2 is not dependent on Acres as much as the other methods and therefore should have a different set of variables.

Table 4. Summary of Data for Layout—Method 4

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	14	24.0	6.5	14.10	1.528	32.69
ACRES	14	70.0	12.0	41.57	4.835	327.34
TPA	14	180.0	65.0	103.21	8.606	1,036.95
SLOPE	14	55.0	15.0	37.86	2.905	118.13
WALKIN	14	9,990.0	250.0	5,205.71	850.962	1,013,793.30
CLOUD	14	1.0	0.0	0.38	0.130	0.24
PRECIP	14	2.0	0.0	0.46	0.170	0.40
TEMP	14	1.0	-1.0	-0.78	0.155	0.34
GRN COND	14	0.0	-1.0	-0.61	0.130	0.24
BRS COND	14	3.0	0.0	1.21	0.214	0.64
BNDRY	14	0	0	0	0	0
SILVI	14	0	0	0	0	0
SCAPE	14	0	0	0	0	0
WILDLIFE	14	0.0	-1.0	-0.93	0.071	0.07
FISHER	14	1.0	-1.0	-0.86	0.143	0.28
WATER	14	0.0	-1.0	-0.93	0.071	0.07
SOILS	14	0.0	-1.0	-0.93	0.071	0.07

Multiple Regression for the Unit Traverse Activity

One basic field method of traversing was reported for all the units. The range of data in Table 5 is wide, and all of the independent variables were used in the regression analysis. The best multiple regression model obtained follows:

$$
\begin{aligned}
\text{Manhours} = & -6.2207 & & R^2 = .798 \\
& +0.80857\ (\text{Acres})\ *** & & n = 259 \\
& +4.1091\ (\text{Scape})\ *** & & \\
& -3.7440\ (\text{Silvi})\ *** & &
\end{aligned}
$$

The equation explains 79.8 percent of the variance in manhours for the Traverse data. Acres was an expected variable but Scape and Silvi were not expected. The sign is correct on Scape, but to come into the equation it must explain the boundary sinuosity better than Bndry. Silvi enters significantly, but with an unexpected sign. This can be explained by having partial cuts with regular boundaries which depend on the marking or cutting prescriptions to lend landscape management attributes, while clearcuts use wavy boundaries to create the landscape effect.

For planning purposes, the equation above or the graph in Figure 4 may be used. The values for Scape and Silvi are found at the beginning of the multiple regression analysis section.

Multiple Regression for Marking

Method 1

The preponderance of the marking data is from leave tree marked units. The data summarized in Table 6 shows a wide range for all measured variables. All the independent variables were used in the regression analysis. An interaction variable of TPA times Silvi was calculated and

Table 5. Summary of Data for Traverse

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	259	500.5	1.0	12.91	2.404	1,496.26
ACRES	259	503.0	1.0	23.37	2.697	1,883.37
TPA	259	425.0	4.0	92.10	2.564	1,702.92
SLOPE	259	90.0	1.0	33.82	1.151	342.98
WALKIN	259	9,990.0	0.0	1,192.81	139.560	5,044,529.22
CLOUD	259	1.0	0.0	0.42	0.030	0.23
PRECIP	259	2.0	0.0	0.23	0.028	0.20
TEMP	259	1.0	-1.0	-0.651	0.042	0.46
GRN COND	259	1.0	-1.0	0.46	0.040	0.41
BRS COND	259	3.0	0.0	1.20	0.054	0.76
BNDRY	259	2.0	0.0	0.34	0.031	0.25
SILVI	259	4.0	0.0	0.63	0.069	1.23
SCAPE	259	3.0	0.0	0.63	0.054	0.74
WILDLIFE	259	1.0	-1.0	-0.37	0.054	0.76
FISHER	259	1.0	-1.0	0.60	0.035	0.32
WATER	259	1.0	-1.0	-0.58	0.037	0.36
SOILS	259	1.0	-1.0	0.63	0.030	0.24

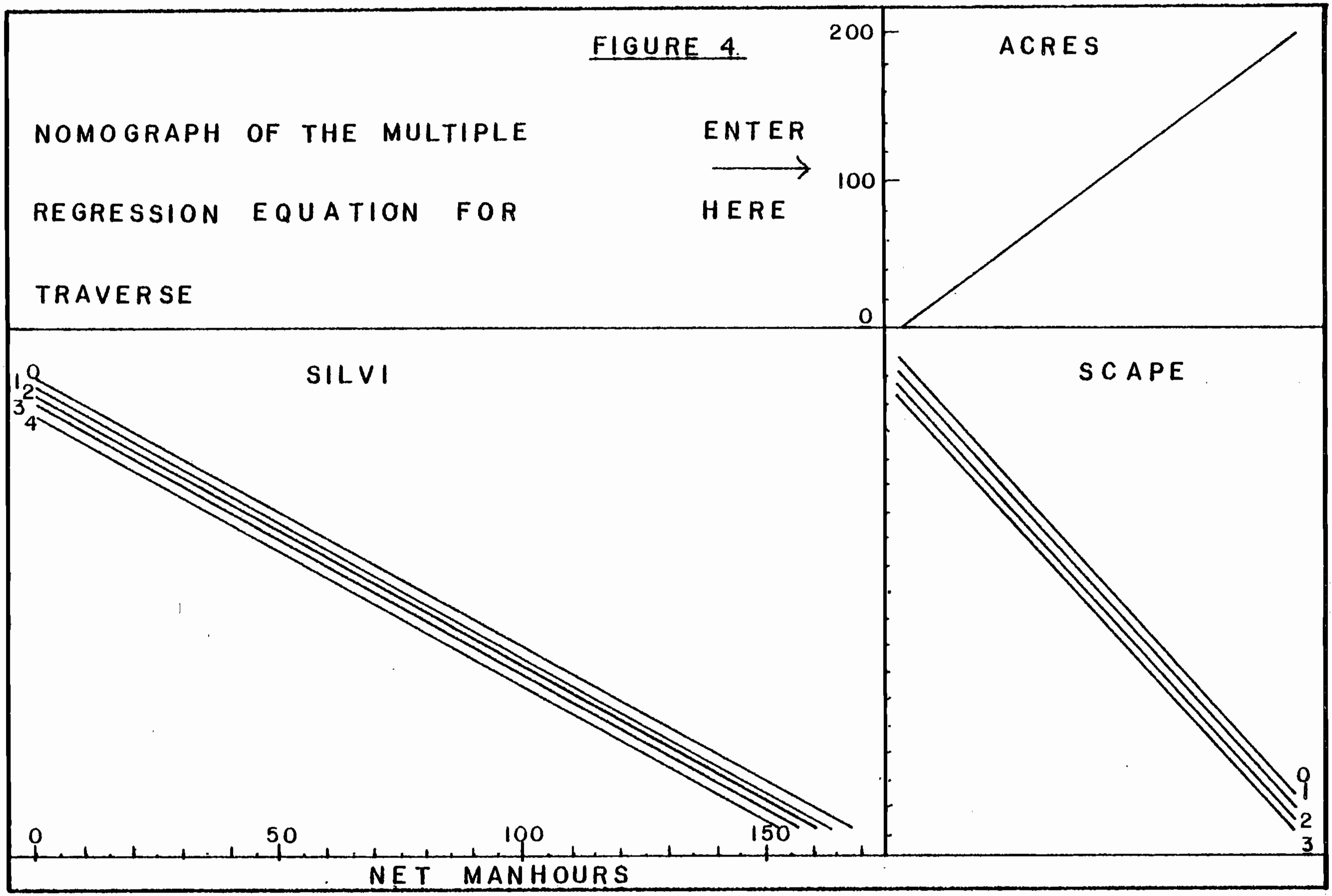


FIGURE 4.

NOMOGRAPH OF THE MULTIPLE REGRESSION EQUATION FOR TRAVERSE

Table 6. Summary of Data for Marking—Method 1

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	86	236.4	0.8	25.72	4.386	1,654.22
ACRES	86	210.0	3.0	31.09	4.272	1,570.11
TPA	86	220.0	4.0	89.72	5.237	2,358.67
SLOPE	86	90.0	5.0	34.63	2.518	545.44
WALKIN	86	9,990.0	0.0	722.54	178.531	2,741,096.98
CLOUD	86	1.0	0.0	0.38	0.052	0.23
PRECIP	86	1.0	0.0	0.15	0.038	0.13
TEMP	86	1.0	-1.0	-0.45	0.077	0.51
GRN COND	86	1.0	-1.0	-0.50	0.070	0.41
BRS COND	86	2.0	0.0	0.92	0.078	0.52
BNDRY	86	1.0	0.0	0.23	0.046	0.18
SILVI	86	4.0	0.0	1.78	0.116	1.16
SCAPE	86	3.0	0.0	0.616	0.098	0.83
WILDLIFE	86	1.0	-1.0	-0.08	0.097	0.81
FISHER	86	1.0	-1.0	-0.43	0.056	0.27
WATER	86	1.0	-1.0	-0.26	0.081	0.57
SOILS	86	0.0	-1.0	-0.44	0.054	0.25

entered as an independent variable. This was done to show the significance of the silvicultural treatment on Manhours as the trees per acre changed.

Silvi not only equates the number of trees to be marked, but also the pattern. The hypothesis is that clumped groups are harder to delineate than evenly spaced leave trees.

The best multiple regression model obtained follows:

$$\begin{aligned} \text{Manhours} = & -8.994 & R^2 = .734 \\ & +0.82183 \text{ (Acres) ***} & n = 86 \\ & +0.053120 \text{ (TPA * Silvi) ***} & \end{aligned}$$

All of the variables have the correct sign and it is interesting that the interaction variable of TPA times Silvi is more significant than TPA or Silvi alone. The Silvi factor in effect doubles, triples, or quadruples the TPA effect. This seems to indicate that more time must be spent weighing the decision of which tree to mark when more trees per acre are available to be marked. Grncond came into the equation as a third variable, but the sign was incorrect and there was no apparent explanation for the sign change. As the contribution was small, Grncond was dropped.

For planning, use the equation above or the graph in Figure 5.

Method 2

Few units were marked for take trees, but the variables involved should be the same as for leave tree marked units. The data in Table 7 shows a range for all of the variables measured, but some of the variables are skewed toward the lower end value.

The best multiple regression model obtained follows:

$$\begin{aligned} \text{Manhours} = & -1.3589 & R^2 = .998 \\ & +1.4516 \text{ (Acres) ***} & n = 12 \end{aligned}$$

FIGURE 5.

NOMOGRAPH OF THE MULTIPLE REGRESSION EQUATION FOR MARKING -- METHOD I

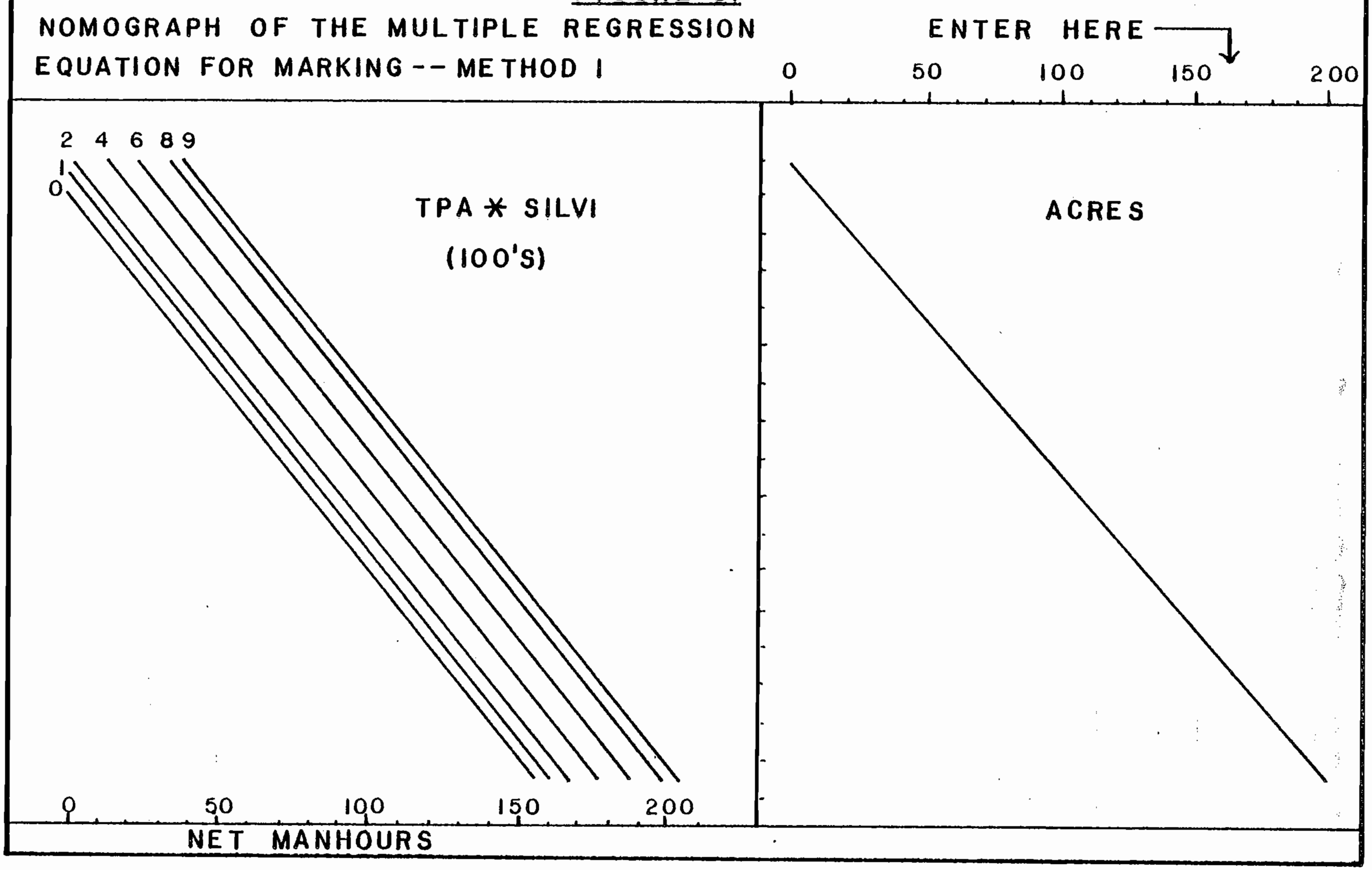


Table 7. Summary of Data for Marking--Method 2

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	12	858.0	7.5	95.42	69.521	57,997.90
ACRES	12	592.0	7.0	66.67	47.835	27,458.06
TPA	12	425.0	22.0	115.67	31.523	11,924.42
SLOPE	12	60.0	1.0	21.75	4.825	279.48
WALKIN	12	1,295.0	0.0	157.97	111.265	148,557.98
CLOUD	12	1.0	0.0	0.19	0.112	0.15
PRECIP	12	1.0	0.0	0.18	0.111	0.15
TEMP	12	0.0	-1.0	-0.61	0.142	0.24
GRN COND	12	0.0	-1.0	-0.80	0.112	0.15
BRS COND	12	2.0	0.0	1.08	0.193	0.45
BNDRY	12	1.0	0.0	0.42	0.149	0.26
SILVI	12	3.0	1.0	1.83	0.207	0.52
SCAPE	12	2.0	0.0	0.75	0.250	0.75
WILDLIFE	12	1.0	-1.0	-0.50	0.261	0.82
FISHER	12	0.0	-1.0	-0.75	0.131	0.20
WATER	12	0.0	-1.0	-0.75	0.131	0.20
SOILS	12	0.0	-1.0	-0.75	0.131	0.20

The small sample size and high coefficient of determination restrict this equation to one variable. The equation describes the low data points and one high data point very closely, but mid-range points are not described as accurately. The one large data point appears to have over-influenced the regression. It is not recommended that this equation be used except for small units under 12 acres.

Multiple Regression for Cruising

Cruising is represented by four different methods, each method taking a different size sample of the population. As all four methods are in use, the factors affecting each method are of interest. Therefore each method was regressed separately.

Method 1

Table 8 summarizes the data for this method, and shows a range for all of the variables measured.

The hypothesis is that Acres and TPA are the primary descriptions with Walkin, Slope, Grncond, and Precip as lesser descriptors.

The best multiple regression model obtained follows:

$$\begin{aligned} \text{Manhours} = {} & 176.24 & R^2 &= .716 \\ & +16.690\ (\text{Wildlife})\ *** & n &= 16 \\ & -1.7627\ (\text{TPA})\ *** & & \end{aligned}$$

The sign on Wildlife is proper, and the effect is to shorten the time required if no special design treatment is used; cause no effect if some design treatment other than Wildlife is used; and increase the time required if there is a wildlife design treatment. This may be caused by the added time taken to check for wildlife reserved tree tags prior to cruising the plot.

TPA enters with a different sign than expected. The only explanation is that more trees per acre mean that the trees are smaller

Table 8. Summary of Data for Cruising--Method 1

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	16	148.5	4.0	30.78	9.76	1,523.38
ACRES	16	210.0	4.0	35.37	12.688	2,575.98
TPA	16	120.0	33.0	79.56	5.325	453.73
SLOPE	16	85.0	5.0	26.69	5.37	461.96
WALKIN	16	2,000.0	0.0	387.50	158.28	400,833.33
CLOUD	16	1.0	0.0	0.36	0.120	0.23
PRECIP	16	1.0	0.0	0.28	0.112	0.20
TEMP	16	0.0	-1.0	-0.94	0.625	0.06
GRN COND	16	0.0	-1.0	-0.58	0.124	0.24
BRS COND	16	3.0	0.0	1.31	0.285	1.29
BNDRY	16	1.0	0.0	0.19	0.101	0.16
SILVI	16	1.0	0.0	0.38	0.125	0.25
SCAPE	16	1.0	0.0	0.25	0.112	0.20
WILDLIFE	16	1.0	-1.0	-0.31	0.237	0.90
FISHER	16	1.0	-1.0	-0.56	0.157	0.40
WATER	16	0.0	-1.0	-0.62	0.125	0.25
SOILS	16	0.0	-1.0	-0.62	0.125	0.25

and have less defect which makes cruising and grading easier. It is also physically easier to measure smaller trees which could partially account for the sign change.

The data were also regressed with the interaction variable of Slope times Precip times Grncond. This multiple regression gave a higher R^2 value, but the interaction variable made no sense if the weather was clear or the ground was wet. Therefore the model selected is the one shown above. This equation goes negative for TPA values of 101 plus and is not recommended for use in planning.

Method 2

This method had the largest data base and the range of each of the measured variables is shown in Table 9. TPA is hypothesized to be more important in this regression than in method 1 since the number of trees, their size, and proximity to the center of the plot are more important in variable plot cruising than in the 1/5 acre plot method. The variable Ac sq and the interaction variables Slope times Brscond and Slope times Grncond times Precip were calculated and added as independent variables in the regression analysis.

The best multiple regression equation obtained follows:

$$\begin{aligned} \text{Manhours} = {} & 8.9394 & R^2 &= .372 \\ & +0.44022\ (\text{Acres})^{**} & n &= 254 \\ & -4.9043\ (\text{Scape})^{**} & & \\ & -0.001148\ (\text{Walkin})^{**} & & \end{aligned}$$

Several multiple regression runs were made on these data, but the interaction variables did not explain the data any better than the equation shown. The only variables to come into any equation are those shown, or Ac sq which was no more significant than Acres.

The sign on Acres is correct, but the sign on Scape and Walkin appears incorrect. The sign on Walkin can be explained by motivation,

Table 9. Summary of Data for Cruising--Method 2

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	254	213.5	0.2	15.73	1.394	493.50
ACRES	254	177.0	1.0	24.95	1.785	809.50
TPA	251	425.0	10.0	87.10	2.475	1,537.97
SLOPE	254	90.0	5.0	34.24	1.234	386.74
WALKIN	254	9,990.0	0.0	1,235.48	132.26	4,443,005.95
CLOUD	254	1.0	0.0	0.40	0.030	0.23
PRECIP	254	2.0	0.0	0.29	0.031	0.25
TEMP	254	1.0	-1.0	-0.58	0.046	0.53
GRN COND	254	1.0	-1.0	0.46	0.042	0.44
BRS COND	254	3.0	0.0	1.20	0.052	0.68
BNDRY	254	2.0	0.0	0.26	0.030	0.22
SILVI	254	4.0	0.0	0.51	0.064	1.03
SCAPE	254	3.0	0.0	0.57	0.053	0.70
WILDLIFE	254	1.0	-1.0	-0.44	0.053	0.71
FISHER	254	1.0	-1.0	-0.65	0.034	0.29
WATER	254	1.0	-1.0	-0.60	0.039	0.38
SOILS	254	0.0	-1.0	-0.67	0.029	0.22

the effects of which were explained in the literature review. Motivation not to take another long walk into a remote unit could have made the cruiser more productive, while a short walk or no walk would have meant lunch at the vehicle and possibly more time taken at lunch or getting back to the work area.

The negative sign on Scape could come from small clearcut units which had to be overcruised to get a proper sample.

For planning purposes use the equation above or the graph in Figure 6.

Method 3

This method has a small data base, but all of the factors measured have some range as shown in Table 10.

Since this method is a 100 percent cruise, the hypothesis is that TPA would be an important variable. The best regression model obtained is:

$$\begin{aligned} \text{Manhours} = {} & 10.353 && R^2 = .904 \\ & + 0.6114\ (\text{Acres})\ {***} && n = 13 \\ & -35.866\ (\text{Temp})\ {*} && \end{aligned}$$

In two regression runs, TPA did not enter until the fifth variable was allowed, and it was always insignificant.

Acres comes in with the correct sign, but Temp comes in with a reversed sign from the hypothesis. Motivation could be the confusing factor. The warm and cool temperatures have a -1 factor for Temp, and hot temperatures have a factor of zero. Therefore hot weather has no effect but cool or warm weather lengthens the time required for cruising. Cold weather with a +1 shortens the time required. This seems to show that people do not waste time in cold weather. They are motivated to get the job done and get back to the warm environment of the vehicle.

This equation works best for units 50 acres and larger. It should be used with caution.

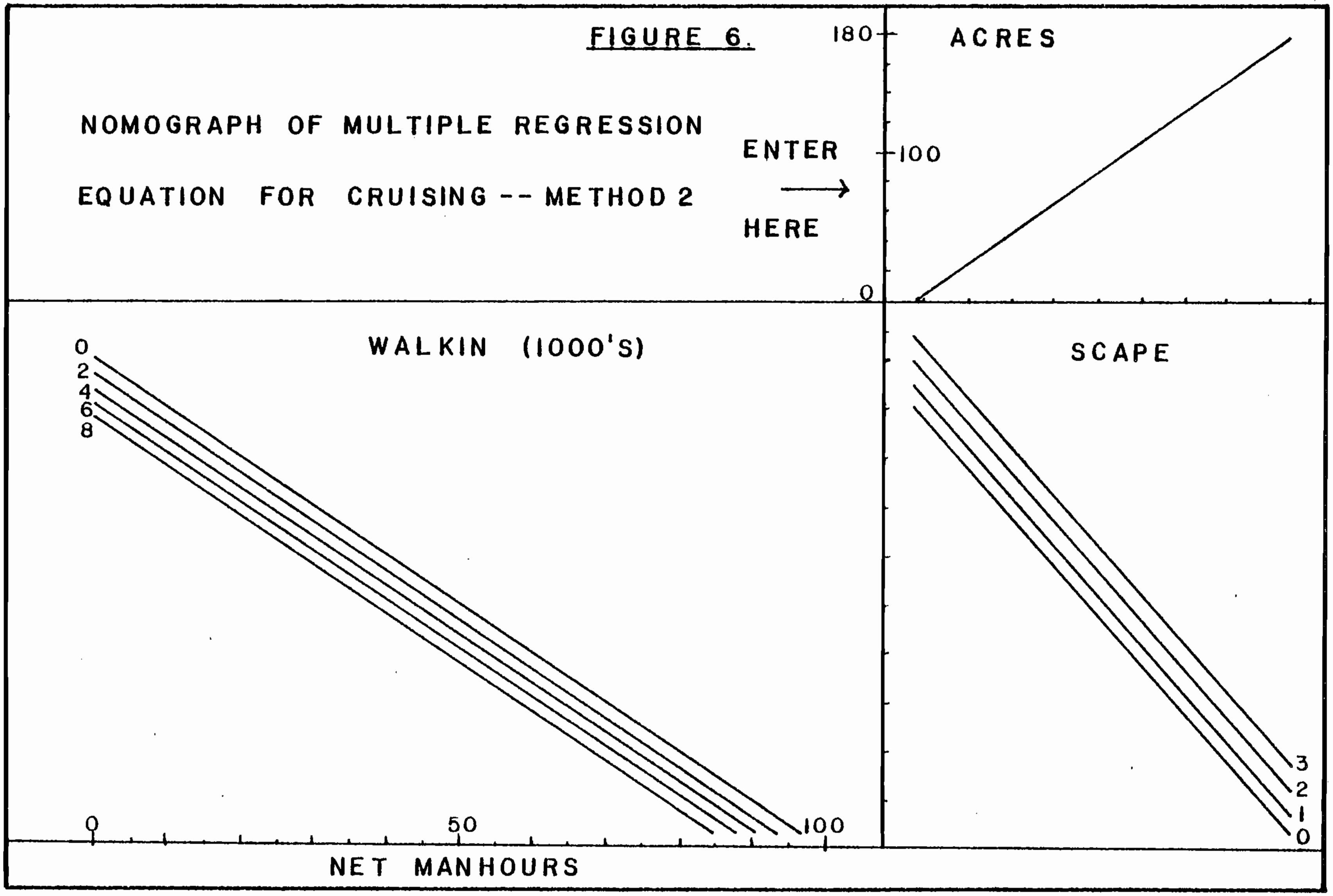


FIGURE 6.

NOMOGRAPH OF MULTIPLE REGRESSION EQUATION FOR CRUISING -- METHOD 2

Table 10. Summary of Data for Cruising--Method 3

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	13	375.0	6.0	78.75	26.940	9,434.66
ACRES	13	520.0	7.0	86.15	39.019	19,792.31
TPA	13	275.0	15.0	106.31	26.927	9,425.56
SLOPE	13	60.0	1.0	26.77	5.747	429.36
WALKIN	13	6,000.0	0.0	750.00	494.72	3,181,666.67
CLOUD	13	1.0	0.0	0.32	0.107	0.15
PRECIP	13	0.6	0.0	0.09	0.052	0.04
TEMP	13	0.0	-1.0	-0.44	0.138	0.25
GRN COND	13	0.0	-1.0	-0.85	0.087	0.10
BRS COND	13	3.0	0.0	1.31	0.286	1.06
BNDRY	13	1.0	0.0	0.23	0.122	0.19
SILVI	13	3.0	0.0	1.23	0.303	1.19
SCAPE	13	2.0	0.0	0.77	0.281	1.02
WILDLIFE	13	1.0	-1.0	-0.54	0.243	0.77
FISHER	13	0.0	-1.0	-0.77	0.122	0.19
WATER	13	0.0	-1.0	-0.77	0.122	0.19
SOILS	13	0.0	-1.0	-0.77	0.122	0.19

Method 4

The data base for this method is very small, but the data were analyzed to see if the change in method brought in a new factor. The data are summarized in Table 11, and as some of the variables are homogeneous, the following hypothesis was used:

Manhours = f(Acres, TPA, Silvi)

The best multiple regression equation obtained is the following:

$$\text{Manhours} = 4.0517 + 0.58519\ (\text{Acres})^{*} \qquad R^2 = .764 \quad n = 4$$

The equation was stopped at one variable since the sample is very small. This equation does not bring in any significant variable different from the first three methods. TPA did come in as the third entering variable, but due to the homogeneity of some of the variables measured, this would indicate no more importance than entering as the fifth variable in larger samples.

This equation should not be used as a predictor because of the small sample size and homogeneity of data.

Review of the four methods of cruising shows Acres as the most important variable except for method 1 where TPA was most important. Acres is the most significant predictor of cruising time as it is significant for the largest amount of data.

Motivation is a likely complicator in the equations as was expected from the literature review.

Multiple Regression for Skyline Profile

The data in Table 12 show a range for all the factors measured. The profile length was not measured, therefore the significance of less

Table 11. Summary of Data For Cruising—Method 4

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	4	25.0	3.0	14.00	6.069	147.33
ACRES	4	41.0	2.0	17.00	9.064	328.67
TPA	4	15.0	5.0	11.25	2.394	22.92
SLOPE	4	35.0	30.0	32.50	1.443	8.33
WALKIN	4	2.0	0.0	1.00	0.408	0.67
CLOUD	4	0	0	0	0	0
PRECIP	4	1	1	1	0	0
TEMP	4	0	0	0	0	0
GRN COND	4	-1	-1	-1	0	0
BRS COND	4	0	0	0	0	0
BNDRY	4	0	0	0	0	0
SILVI	4	2.0	0.0	1.50	0.500	1.00
SCAPE	4	0	0	0	0	0
WILDLIFE	4	-1	-1	-1	0	0
FISHER	4	-1	-1	-1	0	0
WATER	4	-1	-1	-1	0	0
SOILS	4	-1	-1	-1	0	0

Table 12. Summary of Data for Skyline Profile

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	42	53.6	1.0	13.42	2.043	175.24
ACRES	42	138.0	4.0	40.24	4.709	931.45
TPA	42	180.0	5.0	78.43	4.913	1,013.96
SLOPE	42	85.0	15.0	49.09	2.426	247.21
WALKIN	42	9,990.0	0.0	1,874.76	388.872	6,351,313.36
CLOUD	42	1.0	0.0	0.42	0.074	0.23
PRECIP	42	2.0	0.0	0.16	0.065	0.18
TEMP	42	1.0	-1.0	-0.64	0.108	0.49
GRN COND	42	1.0	-1.0	-0.63	0.095	0.38
BRS COND	42	3.0	0.0	0.93	0.115	0.56
BNDRY	42	1.0	0.0	0.24	0.066	0.18
SILVI	42	4.0	0.0	0.69	0.172	1.24
SCAPE	42	3.0	0.0	0.33	0.121	0.62
WILDLIFE	42	1.0	-1.0	-0.50	0.124	0.65
FISHER	42	0.0	-1.0	-0.69	0.072	0.22
WATER	42	1.0	-1.0	-0.59	0.103	0.44
SOILS	42	1.0	-1.0	0.67	0.081	0.28

important variables is all that can be shown by regression analysis for this activity.

The best multiple regression model obtained follows:

$$\text{Manhours} = 5.2001 + 0.15381\,(\text{Acres})^{***} - 4.0596\,(\text{Wildlife})^{*} \qquad R^2 = .233 \quad n = 42$$

The fact that this equation explains little of the variance in Manhours for the activity is understandable. Acres, while correct in sign, is not a good predictor of skyline profile manhours. Length would be a much better predictor, but it was not reported. The presence of a negative sign on Wildlife is confusing. It implies that units with Wildlife restrictions take less time for skyline profiles than units without Wildlife restrictions. Review of the full data shows that a small amount of time was spent on the units designated with Wildlife restrictions. This could easily be due to short skyline profiles in the wildlife designated units.

Another data collection should be made to find the proper variables for this activity. Use of this regression equation for planning is not advised.

Multiple Regression for Wildlife Related Activity

The data in Table 13 show a range for most factors measured. The regression analysis used all independent variables that were not homogeneous.

The best multiple regression obtained follows:

$$\text{Manhours} = -0.37643 + 0.32756\,(\text{Acres})^{***} - 0.00032797\,(\text{Walkin})^{*} \qquad R^2 = .733 \quad n = 35$$

Table 13. Summary of Data for Wildlife Related Activity

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	35	19.5	0.5	2.90	0.554	10.72
ACRES	35	53.0	3.0	11.28	1.458	74.44
TPA	35	113.0	45.0	109.0	2.181	166.47
SLOPE	35	60.0	5.0	21.71	2.090	152.86
WALKIN	35	6,500.0	0.0	1,272.86	271.839	2,586,373.95
CLOUD	35	1.0	0.0	0.06	0.040	0.06
PRECIP	35	1.0	0.0	0.04	0.030	0.03
TEMP	35	0.0	-1.0	-0.97	0.029	0.03
GRN COND	35	0.0	-1.0	-0.94	0.040	0.06
BRS COND	35	3.0	0.0	1.37	0.117	0.48
BNDRY	35	1.0	0.0	0.34	0.081	0.23
SILVI	35	0	0	0	0	0
SCAPE	35	1.0	0.0	0.34	0.081	0.23
WILDLIFE	35	1.0	1.0	1.0	0	0
FISHER	35	0	0	0	0	0
WATER	35	0	0	0	0	0
SOILS	35	0	0	0	0	0

These data were regressed twice. The first time TPA came in highly significant, however it had the wrong sign, and a second analysis was run without TPA.

Slope came in as an insignificant variable after Walkin. Looking at the data summary shows that while the range on slope is wide, most of the data is clustered at the low end which would tend to make it less significant in the regression.

Caution is advised for use of this equation in planning. The unit size is critical as Manhours for units 25 acres or larger are increasingly underestimated.

Multiple Regression for Land Line Retracement

The data base for this activity is small as shown in Table 14, and the most significant factors were not measured. The data were regressed, however, to observe the effect of less significant variables such as Slope and Brscond. Acres was the only significant variable that came in, and it explained 89.8 percent of the variation in Manhours, but it is not an indicator for general data as the acreage of a unit has little bearing on how much land line needs to be retraced. Since no other variable showed significance, this activity should be sampled again, measuring the variables of length and number of corners to be found.

Multiple Regression for Road Location

The data for this activity are summarized in Table 15 and show a range for all of the variables measured. Length is again a factor, but since it was not measured, a model using the measured but less significant variables was regressed. An interaction variable of Grncond times Slope was calculated and entered in the regression analysis.

Table 14. Summary of Data for Land Line Retracement

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	11	76.0	0.9	9.70	6.646	485.89
ACRES	11	400.0	18.0	82.09	33.027	11,998.69
TPA	11	152.0	25.0	61.09	10.015	1,103.29
SLOPE	11	60.0	24.0	48.54	3.375	125.27
WALKIN	11	7,920.0	0.0	2,075.45	789.931	6,863,907.27
CLOUD	11	1.0	0.0	0.49	0.151	0.25
PRECIP	11	1.0	0.0	0.37	0.139	0.21
TEMP	11	0.0	-1.0	-0.91	0.091	0.09
GRN COND	11	0.0	-1.0	-0.60	0.148	0.24
BRS COND	11	3.0	0.0	1.36	0.310	1.05
BNDRY	11	1.0	0.0	0.18	0.121	0.16
SILVI	11	3.0	0.0	0.27	0.273	0.82
SCAPE	11	2.0	0.0	0.64	0.279	0.85
WILDLIFE	11	0.0	-1.0	-0.91	0.091	0.09
FISHER	11	1.0	-1.0	-0.82	0.182	0.36
WATER	11	0.0	-1.0	-0.91	0.091	0.09
SOILS	11	0.0	-1.0	-0.91	0.091	0.09

Table 15. Summary of Data for Road Location

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	20	30.0	0.2	6.46	1.743	60.79
ACRES	20	136.0	13.0	44.20	6.960	968.69
TPA	20	152.0	5.0	91.10	7.065	998.41
SLOPE	20	55.0	25.0	39.75	2.067	85.46
WALKIN	20	3,000.0	0.0	325.00	185.936	691,447.37
CLOUD	20	1.0	0.0	0.30	0.105	0.22
PRECIP	20	2.0	0.0	0.30	0.128	0.33
TEMP	20	1.0	-1.0	-0.70	0.128	0.33
GRN COND	20	0.0	-1.0	-0.65	0.109	0.24
BRS COND	20	3.0	0.0	0.90	0.191	0.73
BNDRY	20	1.0	0.0	0.05	0.050	0.05
SILVI	20	3.0	0.0	0.40	0.222	0.99
SCAPE	20	2.0	0.0	0.10	0.100	0.20
WILDLIFE	20	0.0	-1.0	-0.95	0.050	0.05
FISHER	20	1.0	-1.0	-0.90	0.100	0.20
WATER	20	0.0	-1.0	-0.95	0.050	0.05
SOILS	20	0.0	-1.0	-0.95	0.050	0.05

Some of these variables had significance in Manhours to lay out the unit and were expected to have significance in this regression analysis.

The best multiple regression equation obtained follows:

$$\text{Manhours} = -12.488 + 0.53375\,(\text{Slope})^{*} - 7.5438\,(\text{Precip})^{***} \qquad R^2 = .451 \quad n = 20$$

These data were regressed twice. The first time, an interaction variable of ground condition and slope entered the equation. This variable was nonsensical except for these data, and it had to be dropped.

The effect of Slope has the right sign and proves significant in explaining some of the variance for Manhours. This was expected because slope should produce some effect on this faster paced activity.

Precip enters with a reversed sign which shows the effect of motivation to get the job done and get out of the rain or snow. The use of this equation for a planning tool is not recommended due to the absence of the length variable.

Multiple Regression for Road Traverse

The data base summarized in Table 16 is small but most variables measured have some range. The most important variable, length, was not measured and therefore a model to test the significance of the less important variables was used.

No significant variable was found for this activity, but the first two variables to enter were Brscond and Slope.

The sign on Brscond was unexpected as well as the variable being insignificant. The data explain the incorrect sign. Slope does have the correct sign and appears to explain some of the variation in line with the data.

Table 16. Summary of Data for Road Traverse

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	10	14.0	2.0	7.31	1.044	10.91
ACRES	10	138.0	13.0	44.70	13.545	1,834.68
TPA	10	152.0	60.0	89.20	7.773	604.18
SLOPE	10	75.0	20.0	38.90	5.021	252.10
WALKIN	10	1,200.0	0.0	120.00	120.000	144,000.00
CLOUD	10	1.0	0.0	0.30	0.153	0.23
PRECIP	10	0	0	0	0	0
TEMP	10	0.0	-1.0	-0.81	0.127	0.16
GRN COND	10	0.0	-1.0	-0.81	0.133	0.18
BRS COND	10	2.0	0.0	1.20	0.20	0.40
BNDRY	10	1.0	0.0	0.40	0.163	0.27
SILVI	10	3.0	0.0	0.60	0.400	1.600
SCAPE	10	2.0	0.0	0.50	0.269	0.72
WILDLIFE	10	0.0	-1.0	-0.80	0.133	0.18
FISHER	10	1.0	-1.0	-0.70	0.213	0.46
WATER	10	1.0	-1.0	-0.70	0.213	0.46
SOILS	10	0.0	-1.0	-0.80	0.133	0.18

This activity should be sampled again, measuring the variable of length. Design of the sample should insure a wide range of slopes to measure this variable's effect more fully.

Complete Unit Multiple Regression

The activity data for units which were started and finished during the study period were compiled into data on a unit basis. To be a complete clearcut unit, the minimum activities had to include layout, traversing, and cruising. To be a complete partial cut unit the minimum activities had to include layout, traversing, marking, and cruising.

The units were then categorized by location as Coast or Cascade for the coastal area and Cascade range locations. All the units were put into Allsale for a look at the total unit picture of the study.

Multiple Regression for Coast

Table 17 shows a small sample size and some homogeneity of data for Coast. The following model is hypothesized:

Manhours = f(Acres,Walkin,Brscond,Precip,Cloud,Temp,Bndry, Fisher,Water)

Grncond was left out even though it had variance because the ground was always in the dry range. Slope was left out due to the small range. The interaction variable Brscond times Slope was calculated and entered into the regression analysis.

The best multiple regression model obtained follows:

Manhours = -0.15430		R^2 = .985
+ 2.133 (Acres)	***	n = 6
- 22.468 (Fisher)	**	

Table 17. Summary of Data for Coast Area Units

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	6	168.0	62.0	91.00	16.010	1,537.99
ACRES	6	78.0	31.0	48.00	6.763	274.40
TPA	6	60	60	60	0	0
SLOPE	6	67.0	50.0	60.67	2.860	49.07
WALKIN	6	783.3	0.0	225.0	133.868	107,523.56
CLOUD	6	0.5	0.0	0.27	0.092	0.05
PRECIP	6	0.5	0.0	0.17	0.076	0.03
TEMP	6	0.0	-0.8	-0.48	0.160	0.15
GRN COND	6	-0.3	-0.8	-0.52	0.094	0.05
BRS COND	6	1.9	1.0	1.57	0.123	0.09
BNDRY	6	0	0	0	0	0
SILVI	6	0	0	0	0	0
SCAPE	6	0	0	0	0	0
WILDLIFE	6	0	0	0	0	0
FISHER	6	1.0	0.0	0.50	0.224	0.30
WATER	6	1.0	0.0	0.50	0.224	0.30
SOILS	6	0	0	0	0	0

Acres alone explains 88.8 percent of the variance in Manhours and would be a good indicator by itself. Fisher enters with an incorrect sign, but a look at the data explains this phenomena. The units were split between special design for fisheries or for water quality, perhaps a subtle distinction. Also noted is one large unit in the Water designation without a large Manhour response. This could make Fisher appear more significant than Water and confuse the regression equation. For this reason it would be best for a planning tool to be developed with a better equation and the following is reproduced for that purpose:

$$\text{Manhours} = -16.104 + 2.2313\,(\text{Acres})^{***} \qquad R^2 = .888,\quad n = 6$$

One more significant detail was brought out by regressing the Coast data. The interaction variable of Brscond times Slope entered as the third variable and was significant, but was not included in the equation due to the small sample size.

Multiple Regression for Cascade

Most of the study data came from the Cascade area, and Table 18 shows a range for each variable measured. A model reflecting all of the variables found to be important for the activities is hypothesized for Cascade:

$$\text{Manhours} = f(\text{Acres},\text{TPA},\text{Walkin},\text{Bndry},\text{Scape},\text{Temp},\text{Slope},\text{Precip},\text{Grncond},\text{Wildlife},\text{Silvi})$$

The best multiple regression equation obtained follows:

Table 18. Summary of Data for Cascade Area Units

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	191	269.0	2.3	37.21	3.253	2,021.33
ACRES	191	210.0	1.0	19.19	1.849	652.97
TPA	191	425.0	15.0	88.37	2.801	1,498.93
SLOPE	191	90.0	1.0	33.88	1.352	348.91
WALKIN	191	9,990.0	0.0	1,200.51	125.440	3,005,397.87
CLOUD	191	1.0	0.0	0.35	0.025	0.12
PRECIP	191	1.6	0.0	0.24	0.025	0.12
TEMP	191	0.9	-1.0	-0.45	0.038	0.28
GRN COND	191	0.9	-1.0	-0.27	0.038	0.27
BRS COND	191	2.7	0.0	0.99	0.052	0.52
BNDRY	191	1.0	0.0	0.34	0.037	0.26
SILVI	191	4.0	0.0	0.56	0.078	1.16
SCAPE	191	3.0	0.0	0.68	0.065	0.81
WILDLIFE	191	1.0	-1.0	-0.35	0.065	0.82
FISHER	191	1.0	-1.0	-0.64	0.036	0.24
WATER	191	1.0	-1.0	-0.59	0.043	0.36
SOILS	191	0.0	-1.0	-0.64	0.035	0.23

$$\begin{aligned} \text{Manhours} = {} & 17.177 & & R^2 = .648 \\ & + 1.2498\ (\text{Acres}) & *** \quad & n = 187 \\ & + 7.3499\ (\text{Silvi}) & *** & \\ & - 11.128\ (\text{Scape}) & *** & \\ & - 0.0028287\ (\text{Walkin}) & *** & \\ & + 7.800\ (\text{Bndry}) & * & \end{aligned}$$

Acres, Silvi, and Bndry soil all come into the equation with the correct sign. The overall effect of the total unit must have brought the importance of Silvi to a significant level, which the individual task could not accomplish.

Walkin has a negative sign, and it appears that a strong motivational factor has reversed the expected sign. This implies that the worker accomplishes more the further out he has to walk.

Scape comes in with a reversed sign which is harder to explain. Table 18 shows that most of the Scape data are at the lower end of the scale. Therefore a few large units with large Scape values and small Manhours could reverse the sign.

The equation shown above for the graph in Figure 7 may be used for planning purposes on a total unit basis, but the Scape factor should be looked at closely when entering values into the equation or graph.

Multiple Regression for Allsale

Allsale is mostly comprised of Cascade and the regression equation should be similar. The model hypothesized follows:

$$\text{Manhours} = f(\text{Acres}, \text{Silvi}, \text{Scape}, \text{Walkin}, \text{Bndry})$$

The small amount of data from Coast is not thought to have enough influence on Allsale to bring a special design consideration variable into the regression equation.

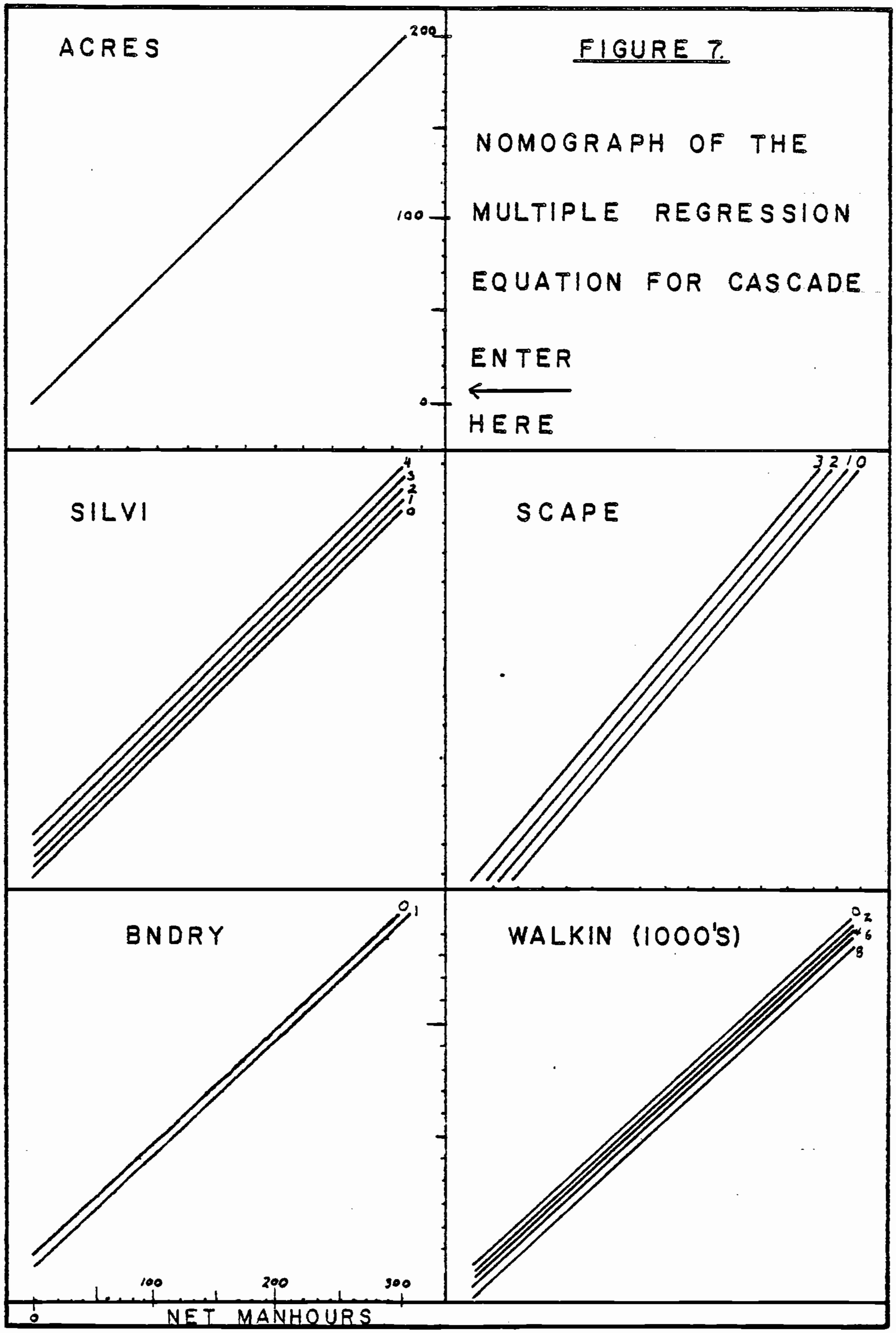


FIGURE 7.

NOMOGRAPH OF THE MULTIPLE REGRESSION EQUATION FOR CASCADE

Table 19. Summary of Data for All Sale Units

VARIABLE	SAMPLE SIZE	MAX VALUE	MIN VALUE	AVERAGE VALUE	STD ERROR OF MEAN	SAMPLE VARIANCE
MANHOURS	197	269.0	2.3	38.85	3.253	2,084.56
ACRES	197	210.0	1.0	20.07	1.837	664.61
TPA	197	425.0	15.0	87.51	2.738	1,476.93
SLOPE	197	90.0	1.0	34.70	1.353	360.77
WALKIN	197	9,990.0	0.0	1,170.80	122.25	2,944,382.85
CLOUD	197	1.0	0.0	0.34	0.024	0.12
PRECIP	197	1.6	0.0	0.24	0.024	0.12
TEMP	197	0.9	-1.0	-0.45	0.038	0.28
GRN COND	197	0.9	-1.0	-0.28	0.037	0.26
BRS COND	197	2.7	0.0	1.01	0.051	0.52
BNDRY	197	1.0	0.0	0.33	0.036	0.25
SILVI	197	4.0	0.0	0.54	0.076	1.14
SCAPE	197	3.0	0.0	0.65	0.064	0.80
WILDLIFE	197	1.0	-1.0	-0.34	0.064	0.80
FISHER	197	1.0	-1.0	-0.60	0.038	0.28
WATER	197	1.0	-1.0	-0.55	0.044	0.39
SOILS	197	0.0	-1.0	-0.62	0.034	0.24

The best multiple regression equation obtained follows:

$$
\begin{aligned}
\text{Manhours} = {} & 17.617 & & R^2 = .664 \\
& + 1.2870\ (\text{Acres}) & *** \quad & n = 193 \\
& - 0.0031302\ (\text{Walkin}) & *** & \\
& - 11.176\ (\text{Scape}) & *** & \\
& + 6.9278\ (\text{Silvi}) & *** & \\
& + 7.4982\ (\text{Bndry}) & * &
\end{aligned}
$$

The equation is nearly the same as the one used for Cascade, with minor differences in the regression coefficients.

Use of this equation is not intended for planning as the area equation for Cascade or Coast would be a better indicator of manhours for proposed work in those areas.

DISCUSSION OF RESULTS

Past studies showed that underbrush, topography, weather, heat, cold, muscle fatigue, motivation and work-rest period affect human performance. In this study, motivation and work-rest period were not measured. However, the effects of these two variables could explain some of the reversed regression coefficients for variables that were measured.

The variables in this study which were significant in explaining the variance in Manhours for separate activities are as follows: Acres, Bndry, Walkin, Scape, Silvi, TPA, Wildlife, and Temp. Comparing this list of variables with the list from past studies does not show much correlation. Temp is the only variable directly related to factors found in other studies, and in this study it had an opposite effect from previous findings. Precip, Grncond, and Slope came into two activity multiple regression equations, but they were insignificant or the data were biased. This leads to the conclusion that the U.S.D.A. forestry worker is in good physical condition, the work-rest period is well balanced, or the work is not physically fatiguing. The first two conclusions should not be discounted, but perhaps it is the fact that the work is not as physically fatiguing as the work studied previously which is the reason for a poor correlation of findings.

Acres, Bndry, and Wildlife enter into the regression equations with the expected signs which shows that they have the effect expected. Acres is the best descriptor variable for most activities, which bases Manhours on the size of the area worked. Bndry, Scape, Silvi, TPA and Wildlife simply add to the effect of Acres.

Bndry and Scape have an effect on the shape of the unit or its placement in the landscape. These two factors should add time to Manhours. Scape does not add time, but this negative result is based on cruise data containing small clearcuts and large partial cuts which resulted in over-cruising the small clearcuts and thereby spending a greater amount of time per acre in the small unit.

Scape and Silvi both have negative signs in the traverse equation. This is again the effect of small clearcuts with sinuous boundaries and large partial cuts with less sinuous boundaries.

TPA and Wildlife have an effect on cruising with TPA reducing the Manhours and Wildlife increasing the Manhours. In this study Wildlife measures whether or not trees are tagged as reserved trees for wildlife. This means that cruisers must check all the trees in a plot for the wildlife tags. This takes more time. The effect of TPA is negative in cruising and positive in marking. With more trees per acre, more time must be taken to make decisions on which trees to mark, or more trees need to be marked. The effect on cruising is that with more trees per acre less time is needed. One reason for this is that smaller trees are easier to measure and grade than larger trees even though there are more small trees to sample. It could also be a motivational effect of enjoying the scenery in a stand of large trees and thus not hurrying the work.

Walkin is a major influence on Manhours, but it came into the regression equations with the correct sign in only one activity, layout. This stems from the fact that workers on layout take their lunch with them as they work. Therefore the further they walk, the longer it takes to complete the layout task. Cruising and wildlife related activities have Walkin as a negative descriptor. This means that the farther the walk, the less time it takes to do the job. Two factors cause this shift in sign. The job of tagging reserve wildlife trees involves carrying metal tags and nails. The weight of the tags causes the worker to load up only the amount of tags which he will use before lunch. He then resupplies at the vehicle after lunch and walks the distance again. The distance was only reported once however. As the distance increases beyond some point, the tree tagger packs a supply of tags into the working area and uses it to resupply. This cuts down on the walking, and motivates him to work faster so that fewer days must be spent on the units with a long walk-in distance. Motivation for a shorter walk and being forced to eat in the woods rather than at the vehicle causes the negative sign in Walkin for cruising also.

The weather related variables of Precip and Temp come into the regression equations with negative signs. This is best explained by motivation. The worker knows that the job has to be done and he does it faster so that he can get back to a warm,dry vehicle. This shows that motivation is a much more influential variable than weather.

The variables which were significant in the unit multiple regression equations reflected the important variables from the activity multiple regression equations. Acres, Silvi, Bndry, Scape, and Walkin were significant and had the same signs as in the activity regressions.

It is noteworthy that only two special design considerations entered the regression equations. Wildlife came in but only from the standpoint of marking or cruising which are tree-related activities. Scape entered with reversed sign and did not reflect the thoughts in the hypothesis. It was thought that the special design considerations would lengthen layout and traversing Manhours, but this effect may have shown up as a Bndry factor rather than a special design factor. This means that most special design considerations are handled as boundary-related factors or they have no significance.

The idea or need for a planning tool such as these equations stems from two facts. First, the easy ground has been logged, and new restrictions increase the manhours required for sale design and layout which district experience does not predict. Second, the supervisory foresters move rapidly through job positions in the U.S.D.A. and most of them do not have the work experience on any one area to be able to accurately predict the manhours needed to do a given task. In the past this has led to extra effort on the part of the presale crew to accomplish the task within the time frame and funds allotted. Use of these multiple regression equations with some thought and adjustment for local conditions should be a way to overcome the inexperience factor and plan the job correctly.

SUMMARY OF USEABLE MULTIPLE REGRESSION EQUATIONS

The Manhours found by use of these equations is the net manhours to do the task. Manhours does not include vehicle travel time.

An example of how to use the graphs and formulae is found in Appendix II.

Activity Derived Equations

Layout

Method 1: Manhours = -6.5809 $\qquad R^2 = .494$
+ 0.48601 (Acres) *** $\qquad n = 264$
+ 6.2563 (Bndry) ***
+ 0.0016494 (Walkin) *

Check the range of data in Summary Table 1 prior to use of this equation or use the graph in Figure 3.

Method 4: $\text{Manhours} = 6.0396 + 0.19389\ (\text{Acres})^{**}$ $\quad R^2 = .376 \quad n = 14$

This equation should be used with caution. Check the range of data in Summary Table 4 prior to use of this equation.

Traverse

$$\text{Manhours} = -6.2207 + 0.80857\ (\text{Acres})^{***} + 4.1091\ (\text{Scape})^{***} - 3.7440\ (\text{Silvi})^{***} \qquad R^2 = .798$$

Check the range of data in Summary Table 5 prior to use of this equation or the graph in Figure 4.

Marking

Method 1: $\text{Manhours} = -8.994 + 0.82183\ (\text{Acres})^{***} + 0.053120\ (\text{TPA*Silvi})^{***}$ $\quad R^2 = .734 \quad n = 86$

Check the range of data in Summary Table 6 prior to use of this equation or the graph in Figure 5.

Method 2: $\text{Manhours} = -1.3589 + 1.4516\ (\text{Acres})^{***}$ $\quad R^2 = .998 \quad n = 12$

This equation should be used only for units 12 acres or smaller in size. Check the range of data in Summary Table 7 prior to use of this equation.

Cruising

Method 2: Manhours = 8.9394 R^2 = .372
+ 0.44022 (Acres) ** n = 254
- 4.9043 (Scape) **
- 0.001148 (Walkin) **

Check the range of data in Summary Table 9 prior to use of this equation or the graph in Figure 6.

Method 3: Manhours = 10.353 R^2 = .904
+ 0.6114 (Acres) *** n = 13
- 35.866 (Temp) *

This equation should be used with caution. It works best for units that are 50 acres or larger in size. Check the range of data in Summary Table 10 prior to use of this equation.

Wildlife Related Activity

Manhours = -0.37643 R^2 = .733
+ 0.32756 (Acres) *** n = 35
- 0.00032797 (Walkin) *

This equation should only be used for planning the time required to tag reserved wildlife trees. The equation should be used with the caution that it increasingly underestimates Manhours for units 25 acres and larger in size. Check the range of data in Summary Table 13 prior to use of this equation.

Complete Unit Derived Equations

Coast

Manhours = -16.104		R^2 = .888	
+ 2.2313 (Acres)	***	n = 6	

This equation should be used with caution as the data base is small. The equation should not be used for units that are smaller than 31 acres. Check the range of data in Summary Table 17 prior to use of this equation.

Cascade

Manhours = 17.177		R^2 = .648
+ 1.2498 (Acres)	***	n = 187
+ 7.3499 (Silvi)	***	
- 11.128 (Scape)	***	
- 0.0028287 (Walkin)	***	
+ 7.800 (Bndry)	*	

Check the range of data in Summary Table 19 prior to use of this equation or the graph in Figure 7.

SUGGESTIONS FOR FURTHER RESEARCH

Future studies need to cover the coast and eastside timber types as they had a small amount of data in this study. The eastside area especially needs this type of study as more skyline cable logging sales are being proposed there. The eastside experience with skyline cable layout is small and serious time constraints are put on the layout people giving them less time than is needed to do a proper job. A good planning tool would help show the amount of time needed to do the job.

The activities of land line retracement, road location, road traversing, and skyline profile had an important variable left unmeasured, length. These activities should be sampled again with length as part of the data collected to provide more useable planning equations.

The equations developed in this paper should be tested by comparing planned time given by the equations with actual time required to do the work.

BIBLIOGRAPHY

Astrand, Per-Olof, MD. and Kaare Rodahl, MD. 1970. Textbook of Work Physiology. McGraw-Hill Book Company, New York. 669 p.

Aulerich, D. Edward, K. Norman Johnson, and Henry Froehlich. November, 1974. "Tractors or Skylines: What's Best for Thinning Young-Growth Douglas-fir?". Forest Industries, Vol. 101 (No. 12): 42-45.

Binkley, V.W. 1965. Economics and Design of a Radio Controlled Skyline Yarding System. U.S.D.A. Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland. Research Paper PNW-25. 30 p.

Binkley, V.W. and H.H. Lysons. 1968. Planning Single-Span Skylines. U.S.D.A. Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland. Research Paper PNW-66. 10 p.

Campbell, J.S. 1972. A Sale Report on Taylor Creek Thinning. Division of Timber Management, Region Six, U.S.D.A. Forest Service, Portland. 13 p.

Conway, Steve. 1976. Logging Practices. Miller Freeman Publications, Inc., San Francisco. 416 p.

Dykstra, D.P. 1975. Production Rates and Costs for Cable, Balloon, and Helicopter Yarding Systems in Old Growth Douglas-fir. Forest Research Laboratory, Oregon State University, Corvallis. Research Bulletin 18. 57 p.

Dykstra, D.P. 1976. Production Rates and Costs for Yarding Cable, Balloon, and Helicopter Compared for Clearcuttings and Partial Cuttings. Forest Research Laboratory, Oregon State University, Corvallis. Research Bulletin 22. 44 p.

Frederick, Vern. 1978. Personal Communication. Assistant Timber Staff, Siuslaw National Forest, Corvallis.

Ingram, John A. 1974. Introductory Statistics. Cummings Publishing Company. Menlo Park, California. 341 p.

McCormick, Ernest J. 1970. Human Factors Engineering. McGraw-Hill Book Company, New York. 467 p.

McGonagill, K.L. 1973. Planning Timber Sales for Helicopter Logging. U.S.D.A. Forest Service, Willamette National Forest, Eugene, Oregon. 33 p.

McGonagill, K.L. 1974. The Effect of Sale Layout on Falling and Bucking. U.S.D.A. Forest Service, Willamette National Forest, Eugene, Oregon. 9 p.

McGonagill, K.L. 1975. Logging Specialists Reference. U.S.D.A. Forest Service, Willamette National Forest, Eugene, Oregon.

Neter, John and William Wasserman. 1974. Applied Linear Statistical Models. Richard D. Irwin, Inc., Homewood, Illinois. 842 p.

Peters, Penn A. 1973. Estimating Production of a Skyline Yarding System. Proceedings, Planning and Decisionmaking as Applied to Forest Harvesting, September 11-12, 1972. Oregon State University, Corvallis. 4 p.

Sinner, Hans-Ulrich. 1973. Simulating Skyline Yarding in Thinning Young Forests. Master of Science Thesis. School of Forestry, Oregon State University, Corvallis. 80 p.

Van Loon, J.H. and L.H. Spoelstra. 1971. Measurement of the Physical Working Capacity and the Physical Condition. IUFRO Division No. 3 Forest Operations and Techniques Publication No. 2, The Norwegian Forest Research Institute, Norway. 7 p.

Vik, Tore. 1971. Maximal Aerobic Power of Norwegian Forestry Workers. IUFRO Division No. 3 Forest Operations and Techniques Publication No. 2, The Norwegian Forest Research Institute, Norway. 6 p.

APPENDICES

APPENDIX I

EXAMPLE FORM EXPLANATION

Sale name, unit #, area and trees/acre are self explanatory. Average slope--slope used in appraisal. Type of cut--condensed silvicultural prescription, in this case a partial cut with 12 leave trees per acre. Special design considerations--any management decision that makes the sale or sale layout more difficult. Activity method description--a brief description of methods used. In the example, layout and recon where done by on the ground recon and use of aerial photos and the unit boundary was marked in some manner. The unit was traversed with a hand compass and cloth tape. If the traverse is done in the office from photos then so indicate. Marking--leave trees were painted and cruising was 1/5 acre plots on a predetermined grid.

Note the instructions and abbreviations at the bottom of the form.

5/3/77 One person reconned and marked boundaries of the unit using aerial photos. He used 1.6 hours to drive to and from the unit and had no walk-in distance to the unit since it was next to the road. He worked 6.4 hours on layout and the weather was clear and cool. The ground was wet and brush easy to walk through.

5/4/77 Two people finished layout and started traverse with hand compass and cloth tape. Weather was overcast and cool, ground was wet and brush easy to walk through. Round trip driving was 1.7 hours and total man hours for each activity was 6.0 hours for layout and 6.6 hours for traverse.

5/5/77 Two people finished traverse. Weather was overcast, raining lightly and cold. Note that the total net man hours on traverse, 11.4 or 5.7 per man do not total to 8.0 when added to travel. Presumably some other work was done in the field or office to take up this slack.

5/10/77 Four men marked leave trees using paint guns. Weather was clear and warm, ground was dry, and brush caused tripping hazards. The change in brush conditions could be logical for several different reasons, but it could also be crew interpretation.

5/11/77 Three men marked leave trees, one man cruised 1/5 acre plots on a predetermined grid.

5/12/77 Two men marked leave trees, two men cruised. The markers finished before the cruisers and joined in the cruising effort as recorders or cruisers.

SALE NAME: ______________________________ UNIT #: ____________________

AREA: ________ ACRES TREES/ACRE: ________ AVERAGE SLOPE: ______ TYPE OF CUT: ______________

SPECIAL DESIGN CONSIDERATIONS: ____
(LANDSCAPE MGT., WILDLIFE, FISHERIES, FIRE MGT., OTHER)

DATE	ACTIVITY	METHOD	# OF PEOPLE	VEHICLE TRAVEL TIME	(FEET) WALK-IN DISTANCE	NET WORK HOURS	WEATHER	GROUND CONDITIONS	BRUSH CONDITIONS

ACTIVITY METHOD DESCRIPTION: ____

AVERAGE SLOPE: average slope of unit in percent.
TYPE OF CUT: silvicultural prescription, ie. partial cut--leave 12 trees per acre.
SPECIAL DESIGN CONSIDERATIONS: restrictions on the timber sale unit such as partial retention--landscape mgt., endangered species habitat enclaves--wildlife mgt., buffer strips--water quality or fisheries.
ACTIVITY: layout (boundary recon and boundary marking), traverse (unit boundary), cruise (volume measurement), mark (marking of take or leave trees), profiles (running skyline profiles on the ground), spur road location (recon and tagging), spur road traverse, land line location, other (specify).
METHOD: describe process of activity, ie. 1. layout--offset from skyline profiles. 2. cruising--grid 1/5 acre plots. 3. marking--leave trees.
VEHICLE TRAVEL TIME: travel from work center to sale unit or jump off point. Hours to closest 1/10. If camped out specify with a c/o.
WALK-IN DISTANCE: good estimate of distance from jump off point to sale unit.
NET WORK HOURS: all time except vehicle travel time. Record to nearest 1/10 hour.
WEATHER: cloud conditions [clear(c), overcast(o)], precipitation [rain(r), snow(s), sleet(sl)], temperature [hot(h), warm(w), cool(c), cold(cd)].
GROUND CONDITIONS: dry, wet snow or ice covered.
BRUSH CONDITIONS: light--easy to walk, few tripping hazards, moderate--some difficulty walking, tripping hazards or obstructions up to 1/2 the time, heavy--hard to walk, constant tripping hazards or dense brush, extremely heavy--no longer walking, instead crawling, swimming or climbing through brush.

ATTACH A TOPOGRAPHIC MAP WITH UNIT BOUNDARY PLOTTED ON IT.

SALE NAME: SAMPLE UNIT #: 3

AREA: 35 ACRES TREES/ACRE: 83 AVERAGE SLOPE: 56% TYPE OF CUT: PC- LEAVE 12 TREES/AC.

SPECIAL DESIGN CONSIDERATIONS: LANDSCAPE MGT. -- MODIFICATION
(LANDSCAPE MGT., WILDLIFE, FISHERIES, FIRE MGT., OTHER)

DATE	ACTIVITY	METHOD	# OF PEOPLE	VEHICLE TRAVEL TIME	(FEET) WALK-IN DISTANCE	NET WORK HOURS	WEATHER	GROUND CONDITIONS	BRUSH CONDITIONS
5/3/77	LAYOUT	1	1	1.6	zero	6.4	c/- /c	WET	LIGHT
5/4/77	"	1	2	1.7	zero	6.0	O - C	WET	LIGHT *
	TRAVERSE	2	2		zero	6.6	O - C	WET	LIGHT
5/5/77	"	2	2	1.6	zero	11.4	O-R-cd	WET	LIGHT *
5/10/77	MARK	3	4	1.8	zero	24.8	C - W	DRY	Mod.
5/11/77	"	3	3	1.8	zero	18.6	C - W	"	"
	CRUISE	4	1		zero	6.2	C - W	"	"
5/12/77	MARK	3	2	1.7	zero	9.6	O-R-C	WET	mod *
	CRUISE	4	2		zero	11.8	O-R-C	WET	mod
	CRUISE	4	2		zero	2.2	O-R-C	WET	mod *
FINISHED									
	UNIT #3								

ACTIVITY METHOD DESCRIPTION: 1. LAYOUT - RECON and mark unit Boundary, used Aerial photos. 2. TRAVERSE - hand compass and cloth tape, 3. MARK - Paint leave trees 4. CRUISE - 1/5 acre plots on grid.

AVERAGE SLOPE: average slope of unit in percent.
TYPE OF CUT: silvicultural prescription, ie. partial cut--leave 12 trees per acre.
SPECIAL DESIGN CONSIDERATIONS: restrictions on the timber sale unit such as partial retention--landscape mgt., endangered species habitat enclaves--wildlife mgt., buffer strips--water quality or fisheries.
ACTIVITY: layout (boundary recon and boundary marking), traverse (unit boundary), cruise (volume measurement), mark (marking of take or leave trees), profiles (running skyline profiles on the ground), spur road location (recon and tagging), spur road traverse, land line location, other (specify).
METHOD: describe process of activity, ie. 1. layout--offset from skyline profiles. 2. cruising--grid 1/5 acre plots. 3. marking--leave trees.
VEHICLE TRAVEL TIME: travel from work center to sale unit or jump off point. Hours to closest 1/10. If camped out specify with a c/o.
WALK-IN DISTANCE: good estimate of distance from jump off point to sale unit.
NET WORK HOURS: all time except vehicle travel time. Record to nearest 1/10 hour.
WEATHER: cloud conditions [clear(c), overcast(o)], precipitation [rain(r), snow(s), sleet(sl)], temperature [hot(h), warm(w), cool(c), cold(cd)].
GROUND CONDITIONS: dry, wet snow or ice covered.
BRUSH CONDITIONS: light--easy to walk, few tripping hazards. moderate--some difficulty walking, tripping hazards or obstructions up to 1/2 the time. heavy--hard to walk, constant tripping hazards or dense brush. extremely heavy--no longer walking, instead crawling, swimming or climbing through brush.

ATTACH A TOPOGRAPHIC MAP WITH UNIT BOUNDARY PLOTTED ON IT.

* FINISHED

APPENDIX II

EXAMPLE PROBLEM

Example problem--to show use of graphs and multiple regression equations.

Given: A 40 acre clearcut unit in a partial retention area on 50 percent slope. Stand density is 75 trees per acre. The walk-in distance is 2000 feet. Vehicle travel time is 1.3 hours roundtrip.

Required: Find the net manhours required to do layout from aerial photographs, traverse with a chain and hand compass, and cruise variable plots on a grid. Compare the total of the activity manhours with the Cascade unit manhours. Calculate the gross manhours by adding the travel time to the net manhours.

Solution:

Nomograph method: (See following figures 3-4, 6-7)

Activity	Net Manhours		
Layout	22.4		
Traverse	34.3		
Cruise	14.4		
Total	71.1	Cascade	47.0

Equation method:

Layout--Manhours = $-6.5809 + 0.48601\ (40) + 6.2563\ (1) + 0.0016494\ (2000) = 22.41$

Traverse--Manhours = $-6.2207 + 0.80857\ (40) + 4.1091\ (2) - 3.7440\ (0) = 34.34$

Cruise--Manhours = $8.9394 + 0.44022\ (40) - 4.9043\ (2) - 0.001148\ (2000) = 14.44$

Total Manhours = $22.41 + 34.34 + 14.44 = 71.19$

Cascade--Manhours = 17.177 + 1.2498 (40) + 7.3499 (0)
- 11.128 (2) - 0.0028287 (2000)
+ 7.80 (1) = 47.06

Gross Manhours Solution: Based on an 8 hour work day, portal to portal.

Hours = hours per day

Vehicle travel time per day = VTT

Number of men in crew = crew

Total vehicle travel manhours = TOTT

$$\frac{\text{Net Manhours}}{(\text{hours-VTT})\ \text{crew}} = \#\ \text{of days}$$

(crew) (# of days) (VTT) = TOTT

Net Manhours + TOTT = Gross Manhours

Layout -- $\frac{22.41}{(8-1.3)(1)} = 3.319$ or 4

(1)(4)(1.3) = 5.2

22.41 + 5.2 = 27.61 gross manhours

Traverse -- $\frac{34.34}{(8-1.3)(2)} = 2.56$ or 3

(2)(3)(1.3) = 7.8

34.34 + 7.8 = 42.14 gross manhours

Cruise -- $\frac{14.44}{(8-1.3)(1)} = 2.15$ or 3

(1)(3)(1.3) = 3.9

14.44 + 3.9 = 18.34 gross manhours

Total Gross Manhours = 88.09

There is no good method for adding vehicle travel time to the unit net manhours found by the Cascade graph or equation.

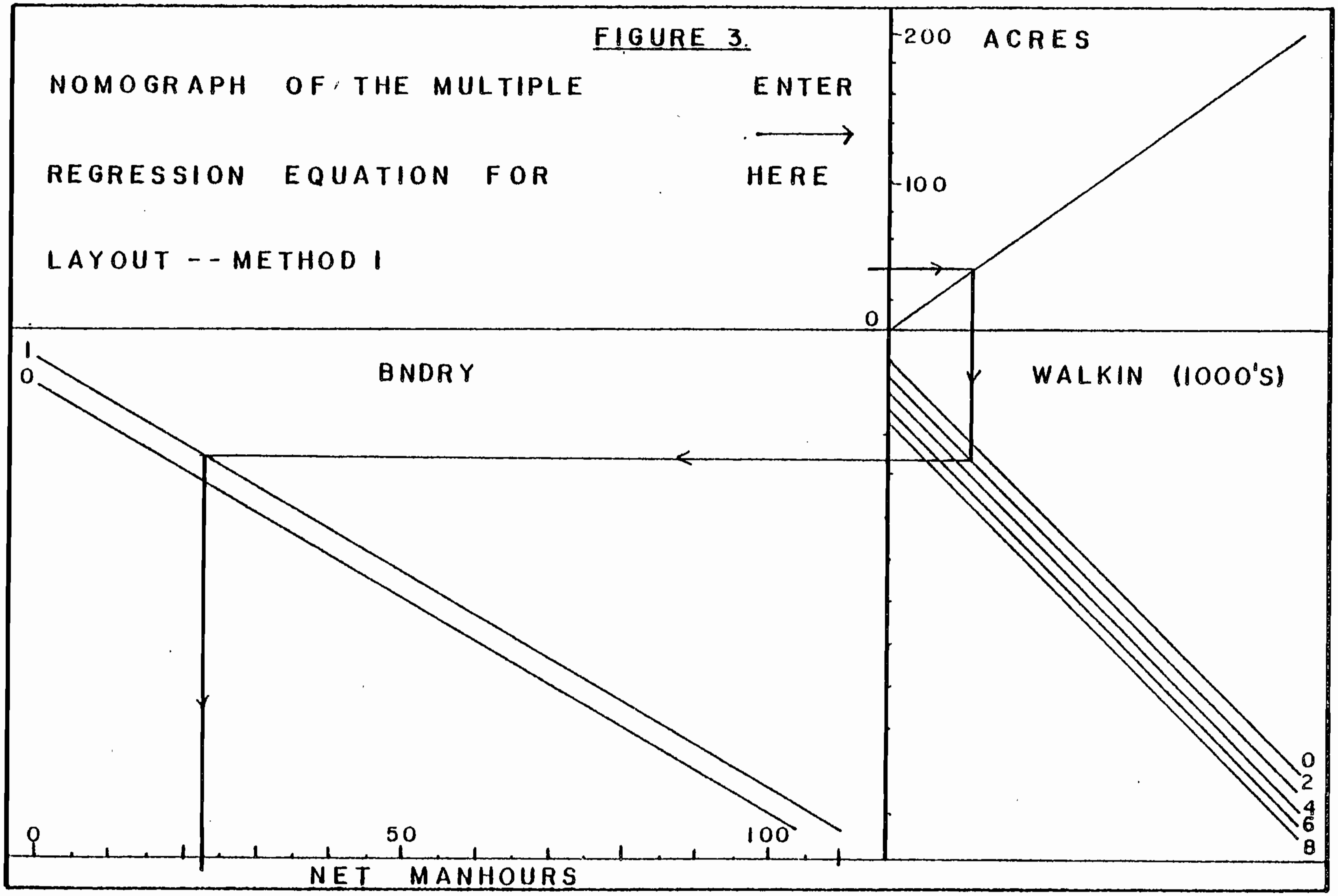


FIGURE 3.

NOMOGRAPH OF THE MULTIPLE REGRESSION EQUATION FOR LAYOUT -- METHOD I

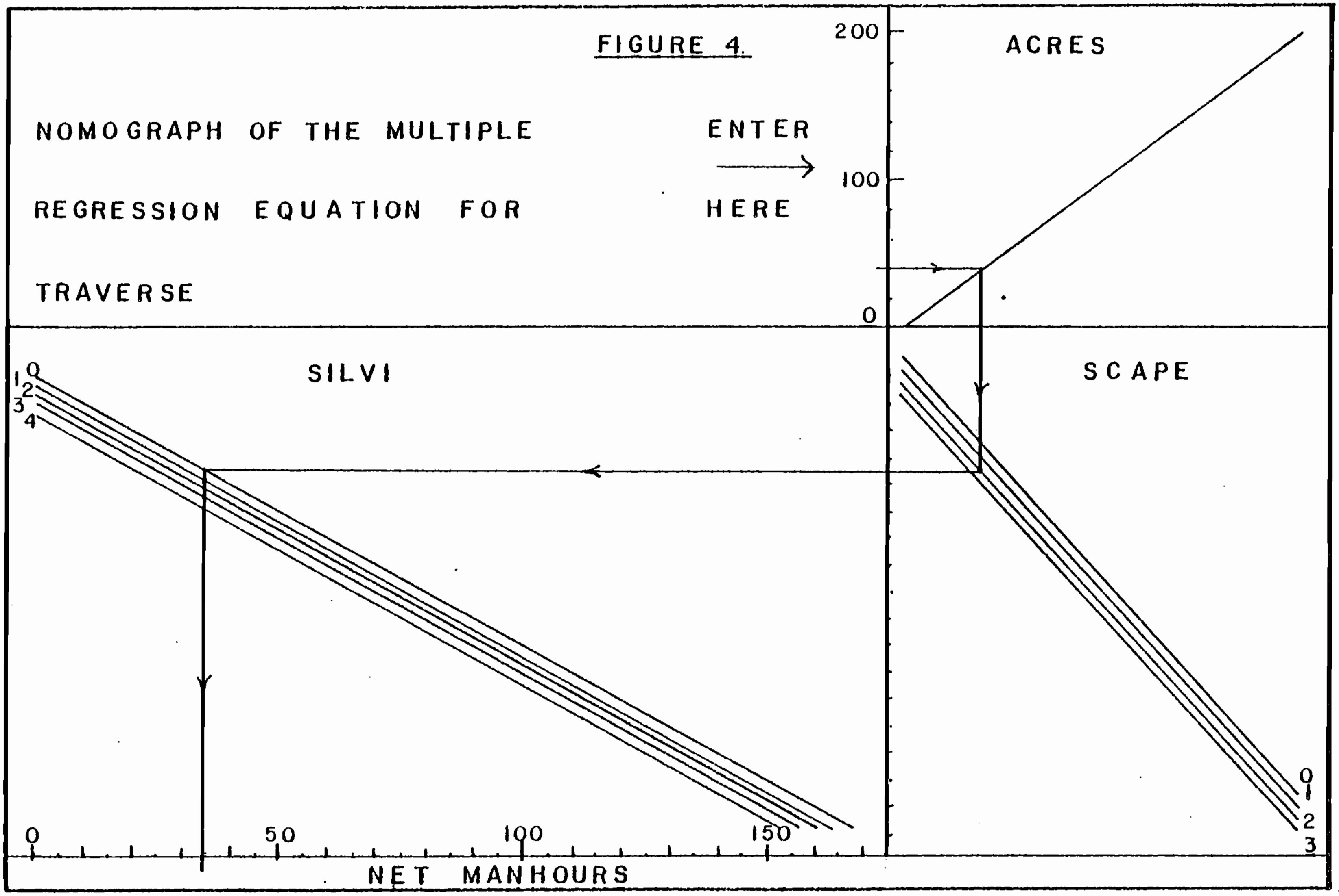


FIGURE 4.

NOMOGRAPH OF THE MULTIPLE REGRESSION EQUATION FOR TRAVERSE

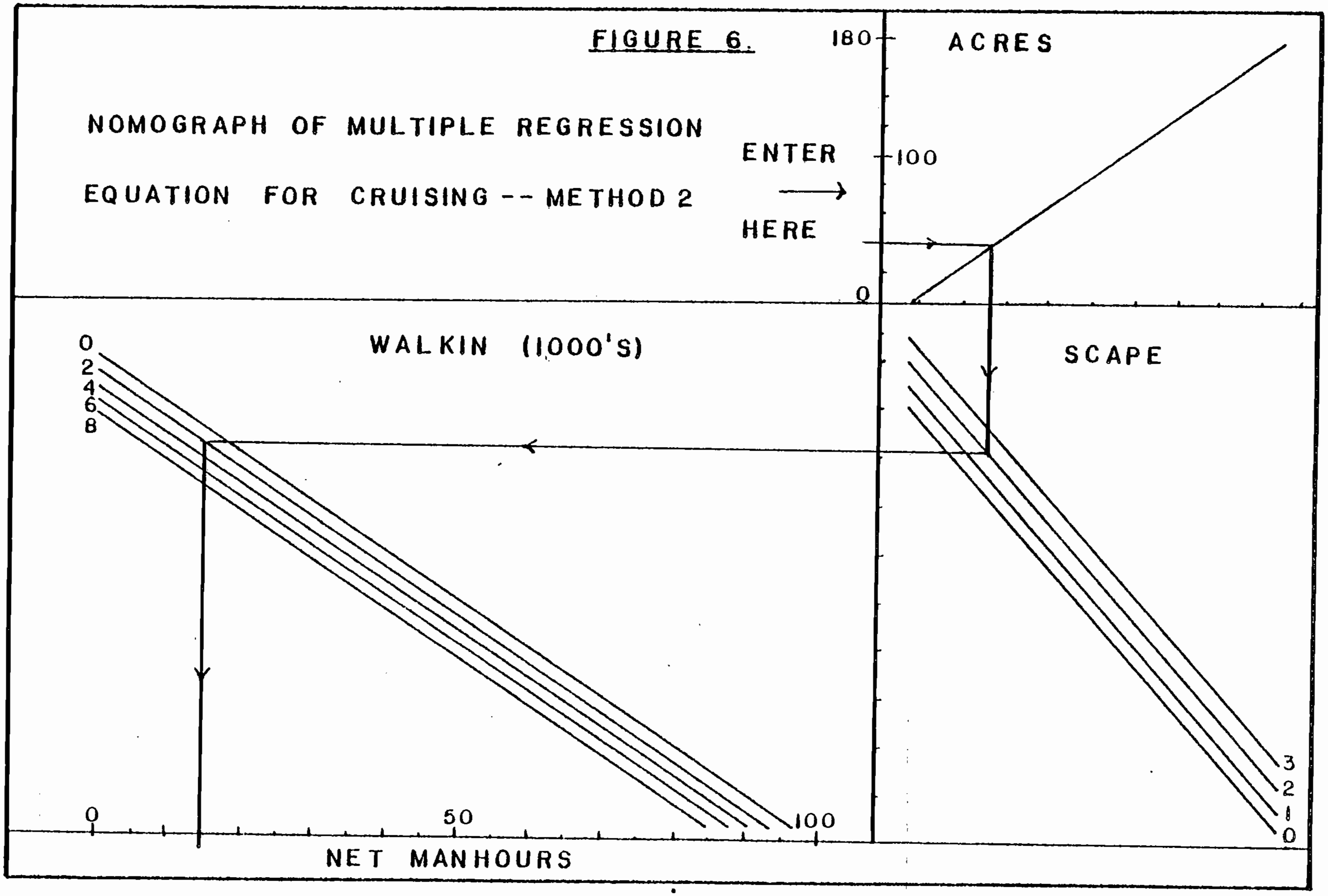
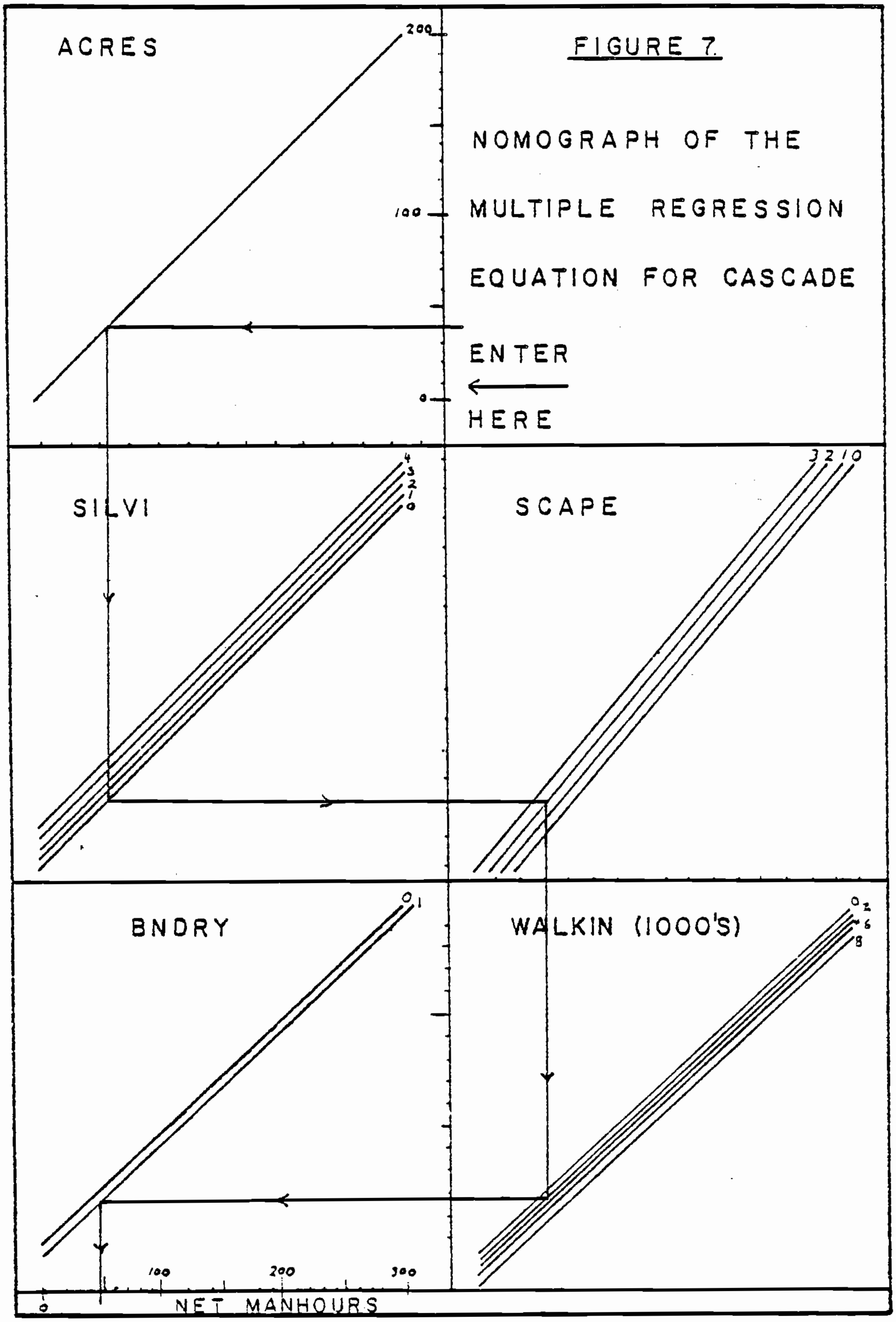


FIGURE 6.

NOMOGRAPH OF MULTIPLE REGRESSION EQUATION FOR CRUISING -- METHOD 2


ACRES
200
100
0
FIGURE 7
NOMOGRAPH OF THE
MULTIPLE REGRESSION
EQUATION FOR CASCADE
ENTER
HERE
SILVI
4
3
2
1
0
SCAPE
3 2 1 0
BNDRY
0 1
WALKIN (1000'S)
0
2
6
8
100
200
300
0
NET MANHOURS